ANNUAL PERFORMANCE REPORT

Title: Use of Suction Piles for Mooring of Mobile Offshore Bases (ONR Grant No. N00014-97-1-0887)

Period: June 1, 1998 – May 31, 1999

Principal Investigator:

Sangchul Bang
Department of Civil and Environmental Engineering
South Dakota School of Mines and Technology
Rapid City, SD 57701

Date: June 10, 1998

Described below are the research activities completed during the second year of the study, from June 1, 1998 to May 31, 1999.

1. Analytical Performance Study of Suction Piles

The suction pile analytical performance study using linear elastic and nonlinear elasto-plastic soil material properties has been completed. The task completion report has been submitted to the Naval Facilities Engineering Service Center (NFESC) after an extensive government review. A copy of the task completion report is included in this report (report99-1.doc in the enclosed CD).

2. Laboratory Model Tests

Laboratory model tests on suction pile installation in sand have been completed. Complete details on the laboratory model test facility, test set-up, soil properties, experimental details, analytical solutions, and calibration of the mobilized effective soil friction angle ratio are included in this report (report99-2.doc in the enclosed CD). Photos of various test facility components are also included.

Model tests on suction pile installation in clay are currently in progress. To date, eight series of tests, each consisting of 3 to 4 nearly identical tests, have been completed. Undrained shear strengths of each soil sample are measured by a miniature vane shear device at three different depths. Results of these eight series tests have been processed and included in this report (report99-3.doc in the enclosed CD).

To simulate the reduction in soil cohesion due to continuing pile penetration during installation, the concept of the "mobilized soil cohesion ratio" has been introduced. The mobilized soil cohesion ratio is defined as the ratio between the soil adhesion necessary to match the applied suction pressure with the soil bearing capacity and the fully available soil cohesion measured from the miniature vane shear apparatus.

Fig – 1 shows the direct relationship between the mobilized soil cohesion ratio (β) and the applied suction pressure. Fig – 2 describes the relationship between β and the pile penetration depth. The effect of the suction pressure can be seen from these two figures, i.e., the value of β decreases as the suction pressure or the pile penetration depth increases. Because of the considerable data scatter, it is necessary to normalize the test results for the calibration of the mobilized soil cohesion ratio. For this purpose, a non-dimensional term is introduced. It includes the effects of the pile dimensions, the soil cohesion at the pile tip, and the applied equivalent external weight due to the suction pressure and the surcharge. The non-dimensional term is expressed as

$$\frac{(P_s + F_b / A)D}{S_u D_p}$$

where P_s is the applied suction pressure inside the pile, F_b is the equivalent external weight, A is the net pile cross-sectional area, D is the pile diameter, S_u is the undrained clay strength at the pile tip, and D_p is the pile penetration depth.

As can be seen from Fig – 3, the mobilized soil cohesion ratio can be expressed very well with little data scatter when it is plotted against the non-dimensional term. As additional model test results become available, they will be included in the analysis and further revision will be made if necessary.

A minimum of 24 series of model tests on suction pile installation in clay are planned to be conducted. The variables include the pile diameter, the surcharge, and the initial pile penetration depth. Each series will consist of 3 to 4 nearly identical tests with undrained shear strength measurements.

3. Validation with Results from Field Installation of Suction Piles

In January 1999, the Naval Facilities Engineering Service Center installed two medium size suction piles off the coast of Port Hueneme. A third pile was installed in March 1999. The piles have a diameter of 5 ft. and a length of 7.5 ft. with an air weight of approximately 1,400 lbs. This is part of its cable burial study program, where the suction piles will be used as cable anchoring devices. The suction piles were designed based on the analytical solutions that were developed by us based on the small-scale laboratory model test results.

All three suction piles were installed successfully. The first and second tests did not yield much detailed measurements, mainly because of the lack of instrumentation and experience. The first pile completely penetrated the full length into the seafloor with a suction pressure of about 5 psi. The second pile was installed similarly but with a fluctuation in suction pressure whose magnitudes varied from 5 to 10 psi. Suction pressures of 5 and 10 psi for the first and second piles were therefore used for the validation study. The third pile however yielded much more detailed relationship between the applied suction pressure and the penetration. A total of seven such relationships became available.

The field measurements of pile penetration vs. applied suction pressure were used to validate the laboratory model test results. Table below describes the field test details and the calibrated mobilized soil cohesion ratio. Fig – 4 shows the resulting plot, which describes the relationship between the non-dimensional parameter and the mobilized soil friction angle ratio. Please note that the non-dimensional parameter does not yet directly include a term describing the effect of the soil friction angle, since only one type of sand

(loose sand) was utilized in the laboratory tests. The condition of sand in the field was slightly denser than the sand used in the laboratory tests, i.e., 30 degrees for the laboratory sand and 34 degrees for the field sand. This may be the primary reason why the field test data generally lie slightly above the laboratory test data. In near future, the effect of the soil friction angle will be incorporated in the non-dimensional term when additional model tests with different sand friction angle become available.

Input Data:

Diameter of Pile:	5.0 feet
Thickness of Pile:	0.25 inches
Length of Pile:	7.5 feet
Pile Buoyant Weight:	1,200.0 lbs
Water Depth	41.0 feet
Soil Buoyant Unit Weight:	60.0 pcf.
Sea-Water Unit Weight:	64.0 pcf.
Cohesion:	0.0 psf.
Friction Angle:	34.0 degrees
Surcharge:	100.0 lbs

Analysis Results:

Identification	Suction Pressure (psf)	Penetration Depth (ft)	β
Field Test - 1	707.5	7.50	0.826
Field Test - 2	1,415.0	7.50	0.982
Field Test - 3	288.0	0.50	1.070
	360.0	0.83	1.051
	432.0	1.75	1.005
	504.0	2.50	0.979
	648.0	2.58	0.996
	792.0	5.50	0.898
	936.0	6.00	0.905

4. Comparison of Field Tests on Mooring Lines

Results of the previous centrifuge model tests have been used to provide validation of the analytical solution by comparing the predictions with the field test results conducted by the Naval Civil Engineering Laboratory in Indian Island, Puget Sound, Washington. Complete results of the study are included in this report (report99-

4.doc in the enclosed CD).

Fig – 1 Relationship between β and Suction Pressure

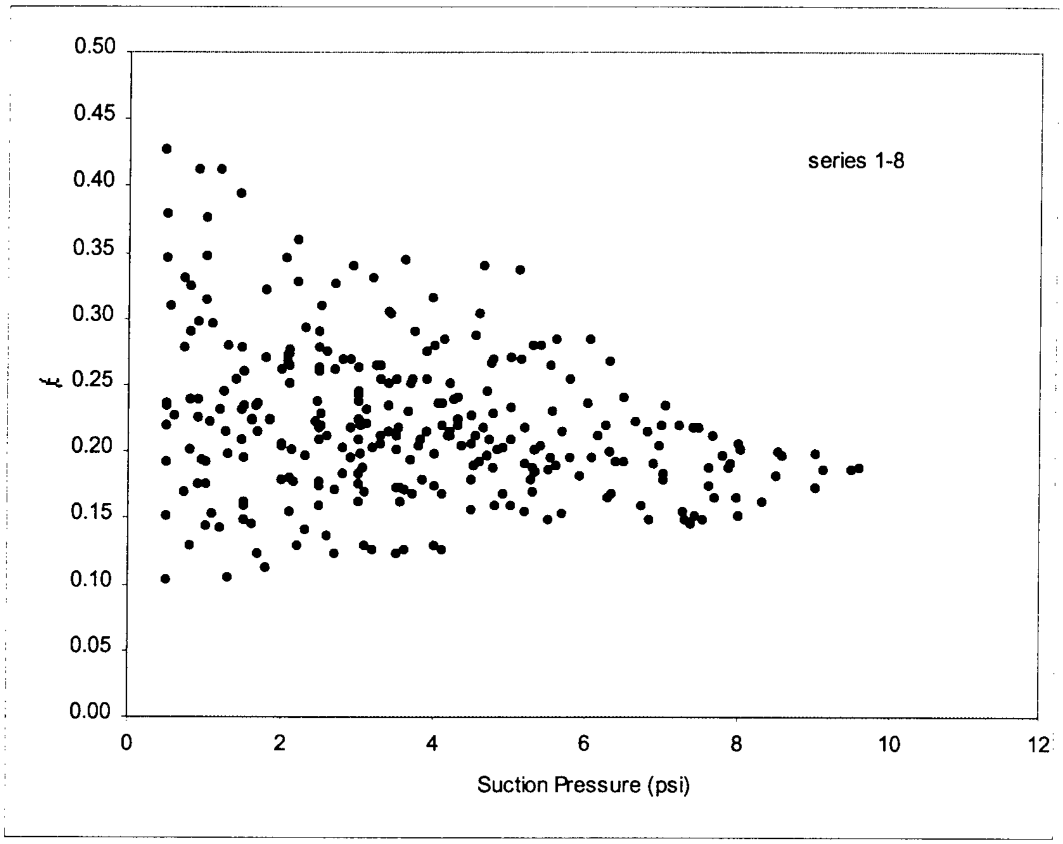


Fig – 2 Relationship between β and Pile Penetration Depth

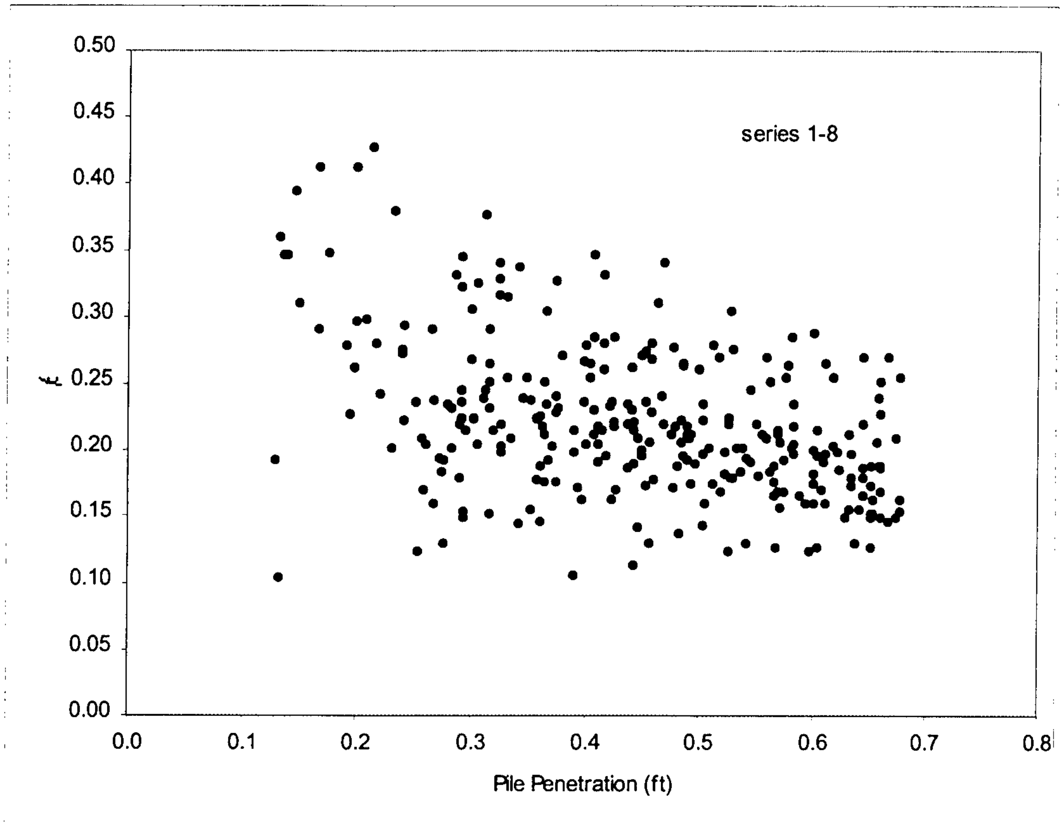


Fig – 3 Relationship between β and Non-dimensional Parameter

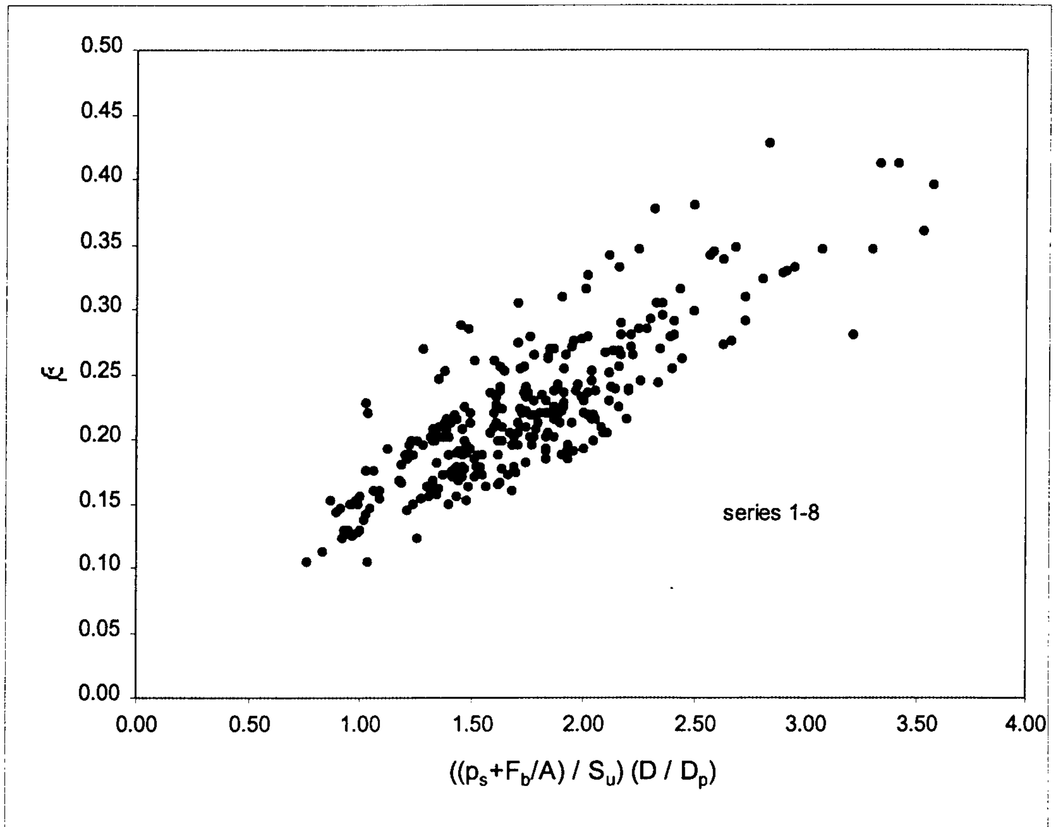
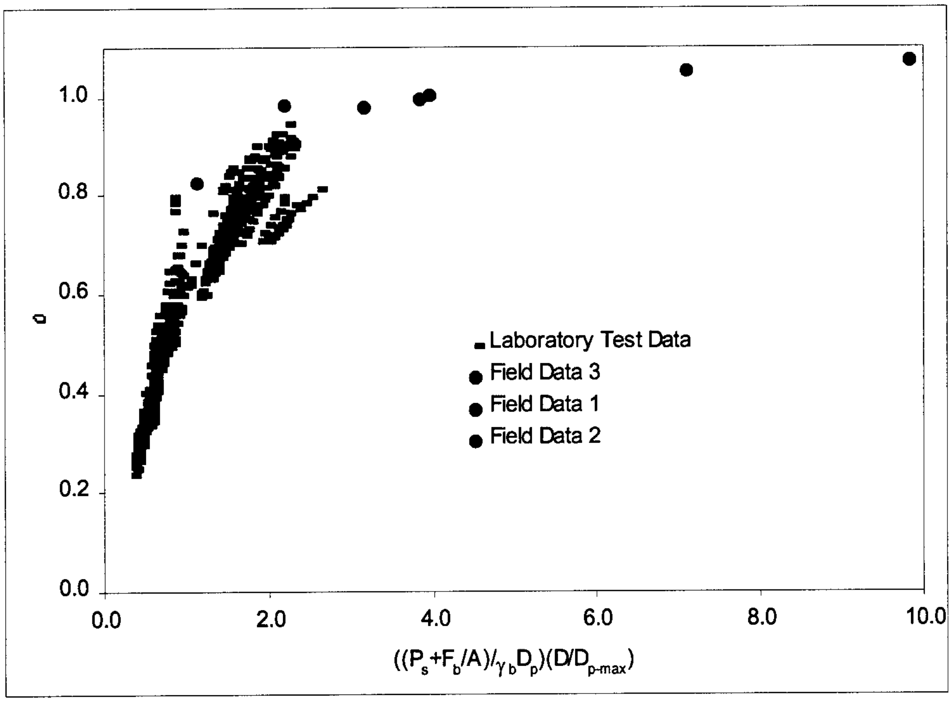


Fig – 4 Field Measurements Data



LABORATORY MODEL TESTING ON SUCTION PILES IN SAND AND ANALYTICAL SIMULATION OF INSTALLATION

1. INTRODUCTION

The final objective of this study is to develop an analytical solution that can be used to help install suction piles successfully in the field. The analytical solution should be capable of estimating the correct suction pressure that can safely penetrate the pile into the sandy seafloor without creating any instability at a given pile penetration depth. The correct suction pressure value should be provided in a range. The lower bound value corresponds to the suction pressure inside the pile that can barely overcome the pile bearing capacity so that the pile can penetrate into the soil. The upper bound suction pressure is the one that initiates the soil boiling state, at which time the soil becomes unstable and starts to flow into the pile. Eventually the pile inside will be filled with sand and therefore the pile installation becomes incomplete.

The analytical solution should consider the effect of water flow from the outside soil surface through the tip of the pile to the inside soil surface of the pile resulting from the pressure difference caused by the applied suction pressure. The lateral flow of the water at the tip of the pile and the upward flow inside the pile obviously loosen the sand density, which in turn reduces the strength of the sand. To simulate this soil loosening, the concept of the "mobilized effective soil friction angle ratio" has been introduced. The mobilized effective soil friction angle ratio is the ratio between the mobilized effective friction coefficient and the available effective friction coefficient of the soil. The mobilized effective

friction coefficient is the required soil friction coefficient so that the pile-soil system is in a balancing state having the factor of safety of 1.0. The available friction coefficient is the maximum friction value of the soil.

To quantitatively describe the variation of the mobilized effective soil friction angle ratio, a series of laboratory model tests on suction piles in sand have been conducted. Since the water pressure gradient varies along the pile length, the mobilized effective soil friction angle ratio varies also. However, the analytical solution method that incorporates the variable mobilized effective soil friction angle ratio, which is a function of many parameters, will be extremely complicated. Instead, an approach has been taken to utilize the average mobilized effective soil friction angle ratio, i.e., a single representative value at a given state. The laboratory model tests have been designed to provide this information.

The purpose of the laboratory model tests is to produce relationships between the applied suction pressure inside the pile and the resulting pile penetration without causing any soil instability under various conditions of the applied surcharge, the pile diameter, and the initial pile penetration. The relationships are then used to produce the description of the average mobilized effective soil friction angle ratio.

The laboratory model tests utilized two plexiglass circular tubes that have different diameters and thicknesses. Four different surcharge weights were applied on top of the pile to simulate the weights of the pile and the superstructure in the field. In addition, three different pile initial penetration depths were used to examine its effect on the pile installation.

2. TEST FACILITY

2.1 Model Test Tank

The equipment used for the pile installation tests is shown schematically in Figure 1. Photos of major equipment associated with the test facility are included in Appendix-1. The test tank consisted of two sections of a 2.0 ft. diameter heavy duty PVC water pipe (Figure 2). The lower section was made from the flange of the pipe and was attached with turnbuckles to a one half inch thick steel plate. In order to provide a waterproof seal, a one half inch thick neoprene sheet was placed between the steel plate and the pipe flange. For backwash and drainage purpose, a perforated steel plate was covered with a geofabric to prevent the sand from washing into the backwash chamber. A 4.9 ft. straight pipe section was then installed into the top portion of the flange and sealed with a standard pipe seal.

Prior to testing, the tank was filled with water, and sand was pluviated into the tank. The sand was placed to within 0.5 ft of the top of the pipe. The density of sand was kept constant by maintaining the height of the sand column at the same height at the beginning of each test through a combination of backwashing and agitation. Backwashing was done by applying a high water pressure through the chamber below the soil column and agitation was done with a perforated plastic pipe with a high water pressure.

2.2 Model Piles

The model tests were carried out with two model piles. The larger model pile consisted of 0.534 ft. outside diameter and 5.04 ft. long Plexiglas pipe with a wall thickness of 0.245 inches. The smaller one had a 0.415 ft. outside diameter and 5.0 ft. long Plexiglas

pipe with a wall thickness of 0.265 inches. The tip of the pile was beveled at an angle of approximately 30 degrees with the longitudinal axis of the pile. The details of the test piles are summarized in Table 1. The top of the pile was capped with a Plexiglas disk and a vacuum pipe leading to a vacuum pump was attached through the center of the plate. Pressure transducers to record the level of vacuum were attached near the top of the pile and on the pipe outside the pile. The vacuum pipe was equipped with two moisture collection chambers and a dessiccator chamber to minimize the amount of moisture entering the vacuum pump. A vacuum control valve was attached to the pipe between the dessiccator chamber and the vacuum pump.

Penetration of the pile was measured with a roller wheel assembly connected to a potentiometer. The assembly was fixed to the top of the model tank. The roller wheel was placed against the wall of the pipe. In order to eliminate possible slippage, a narrow sand paper strip along the pipe outside surface was attached to improve the roller friction.

3. SOIL PROPERTIES

The soil used for experiments consisted of cohesionless fine sand obtained commercially and used for sand blasting. The material is a sub-rounded, poorly graded sand with 100 percent passing the number 16 and less than 1 percent passing the number 100 and 200 US standard sieves. The friction angle of the soil is 30 degree. The total unit weight of the soil is 120 pcf.

4. EXPERIMENT DETAILS

4.1 Pile Placement

Prior to installation of the pile, the sand was backwashed and agitated to raise its surface to a preset level corresponding to a total unit weight of 120 pcf. The pile was then manually pushed into the sand to a preset initial penetration depth, and vacuum was applied and gradually increased until movement started. Extreme care was taken in increasing the vacuum pressure not to create a boiling condition, as this would fill up the pile with sand quickly and prevent further penetration.

4.2 Test Procedure

After the pile was seated, all instruments were set to zero reading on the digital data acquisition system (DAS), and the soil and water column heights rechecked. Vacuum was then carefully applied in increments by opening and adjusting the vacuum control valve (Figure 1) until the pile started to move. The vacuum level was then maintained at that level until movement ceased. As long as the pile moved, vacuum pressure readings were taken (manually for test series 1 ~ 6 and digitally for test series 7 ~ 18). In case of manual reading, each data was collected at every 1/8 inches. DAS increments were set at 10 second intervals. Pile movement generally occurred in increments of 1/8 to 1/4 inches or less. Water level reading both inside and outside were taken every third pile movement. By carefully adjusting the pressure level inside the pile, boiling condition was prevented. However the soil column inside the pile was observed to rise slightly. It was felt that this was due to both the

displacement of the sand caused by the pile penetration and the soil volume expansion caused by the upward water flow gradient inside the pile. The soil column heights were recorded manually.

As the pile penetration progressed under constant vacuum level, the time interval between movement increments increased. If the time interval between increments reached five minutes or longer, the vacuum pressure inside the pile was increased gradually until the movement again commenced, and the procedure repeated until the pile was fully penetrated or until a boiling condition inside the pile occurred.

5. ANALYTICAL SOLUTION

In order to successfully penetrate the suction pile into the seafloor, the soil resistance must be overcome. The resistance of the pile is the pile bearing capacity corresponding to the state of the pile penetration. The resulting pile penetration depth at given applied suction pressure can therefore be determined from the equilibrium. The equilibrium requires that the bearing capacity of the pile equal to the external force including the weight of the pile, the applied surcharge, and the suction pressure. When a constant suction pressure with the resulting total external force exceeding the pile bearing capacity is applied, the pile starts to penetrate until it reaches a depth where the pile bearing capacity equals the external force. As the suction pressure increases again, the external load also increases and the pile starts to penetrate into the soil until the next equilibrium is reached. This procedure will repeat until the pile installation is completed or the pile does not penetrate any further. It is noted that

during the installation process the suction pressure should not exceed the critical pressure that may induce the boiling of the sand inside the pile.

As explained previously, the density of the sand near the tip and inside the pile may be loosened due to the upward water flow caused by the suction pressure. This will result in a reduction of the soil friction angle and the frictional coefficient between the soil and the pile. To quantify this reduction in frictional capacity, the concept of the "mobilized effective soil friction angle ratio", α, has been introduced. It is defined as

$$\alpha = \frac{\tan \phi'_m}{\tan \phi'} \tag{1}$$

where

ϕ'_m = mobilized effective soil friction angle necessary for the equilibrium between the external force and the pile bearing capacity

ϕ' = fully available effective soil friction angle

The variation of α has been determined from the results of laboratory tests by matching the calculated pile penetration with the observed pile penetration at given conditions as described in chapter 6.

5.1 Pile Bearing Capacity

The pile bearing capacity can be determined from the pile tip bearing capacity and the frictional capacity. Depending upon the pile diameter to length ratio, the soil inside the pile may behave as a unit with the pile or independent to the pile. The total bearing capacity of the former case will be the sum of the tip bearing capacity based on the gross cross-sectional area of the tip and the frictional capacity developed outside the pile minus the buoyant weight of the soil inside the pile. The latter case however should consider the tip bearing capacity based on the net cross-sectional area of the tip and the frictional capacity developed both inside and outside the pile. The total pile bearing capacity, Q, therefore can be expressed as the smaller of these two cases, i.e.,

$$Q = \text{minimum } [Q_1, Q_2] \qquad (2)$$

where

$Q_1 = Q_{outside} + Q_{inside} + Q_{net,\ tip}$

$Q_2 = Q_{outside} + Q_{gross,\ tip} - W_{insde\ soil}$

$Q_{outside}$ = frictional capacity between the outside surface of the pile and the soil

Q_{inside} = frictional capacity between the inside surface of the pile and the soil

$Q_{net,tip}$ = tip bearing capacity of the net cross-sectional area of the pile

$Q_{gross,tip}$ = tip bearing capacity of the gross cross-sectional area of the pile

$W_{insde\ soil}$ = effective weight of the soil plug inside the pile

5.1.1 End Bearing Capacity

The general ultimate bearing is expressed as

$$q_u = c\,N_c + q'\,N_q + 0.5\,\gamma'\,D\,N_\gamma \tag{3}$$

where

c = cohesion

q' = effective overburden at the tip of the pile

D = diameter of the pile

γ' = buoyant unit weight of the soil

N_c, N_q, and N_γ = bearing capacity factors

It should be noted that all parameters are in effective terms due to the drained condition prevailing during the installation of suction piles in sand. The general ultimate bearing capacity equation is further modified as shown below to include the effects of the pile shape and the depth.

$$q_u = c\,N_c\,F_{cs}\,F_{cd} + q'\,N_q\,F_{qs}\,F_{qd} + 0.5\,\gamma'\,D\,N_\gamma\,F_{\gamma s}\,F_{\gamma d} \tag{4}$$

Bearing Capacity Factors

The bearing capacity factor N_c proposed by Prandtl (1921), N_q by Reissner (1924), and N_γ by Caquot and Kerisel (1953) and Vesic (1973) are shown below.

$$N_q = e^{\pi \tan\phi'_m} \tan^2(45^o + \frac{\phi'_m}{2}) \quad (5)$$

$$N_c = (N_q - 1) \cot\phi'_m \quad (6)$$

$$N_\gamma = 2(N_q + 1) \tan\phi'_m \quad (7)$$

where

ϕ'_m = mobilized effective soil friction angle

Shape and Depth Factors

The shape factors can be evaluated by the equations suggested by De Beer (1970) as shown below.

$$F_{cs} = 1 + \frac{B}{L}\frac{N_q}{N_c} \quad (8)$$

$$F_{qs} = 1 + \frac{B}{L}\tan\phi'_m \quad (9)$$

$F_{\gamma s}$ = 0.6 for circular sections (10)

The depth factors extended by Hansen (1970) used in this study are shown below.

$$F_{cd} = 1 + 0.4\ k \quad (11)$$

$$F_{qd} = 1 + 2\tan\phi'_m (1 - \sin\phi'_m)^2\ k \quad (12)$$

$$F_{\gamma d} = 1 \quad (13)$$

where

$$k = \frac{D_p}{D} \qquad \text{for } \frac{D_p}{D} \le 1$$

$$k = \tan^{-1}\left(\frac{D_p}{D}\right) \qquad \text{for } \frac{D_p}{D} \ge 1$$

D_p = pile penetration depth

D = pile diameter

5.1.2 Pile Frictional Capacity

The pile frictional capacity, q_s, can be estimated from

$$q_s = \sum_{i=1}^{N} \int_0^{L_i} \pi D f_s dz \qquad (14)$$

where

D = pile diameter

$f_s = c + \sigma'_1 K_o \tan\delta$

c = cohesion

σ'_1 = effective overburden pressure at a give depth

K_o = lateral earth pressure coefficient of the soil

δ = interface friction angle between the pile and the soil

L_i = pile embedment length within i^{th} soil layer

N = number of soil layers

It is assumed in the above expression that the soil arching does not take place due to the small aspect ratio associated with suction piles. When the seafloor soil consists of a single, uniform soil layer along the entire pile embedment length, the effective overburden at the mid-depth of the pile can be used to obtained the total pile frictional capacity without carrying out the integration.

5.1.3 Pore Water Pressure

The effective overburden pressure, σ'_1, can only be calculated by subtracting the pore water pressure from the total overburden pressure. The pore water pressure at any given point within the soil must consider the hydrodynamic condition due to the flow of water created by the suction pressure.

Since the permeability of the sand is relatively high and the boundary conditions do not change at a given suction pressure, a two-dimensional steady state water flow problem as shown in Figure 3 can be assumed and solved.

The governing differential equation of steady state water flow in two-dimensions is expressed as

$$k_x \frac{\partial^2 h}{\partial x^2} + k_y \frac{\partial^2 h}{\partial y^2} = 0 \tag{15}$$

where

k_x = hydraulic conductivity along x direction

k_y = hydraulic conductivity along y direction

h = total head

Assuming isotropic soil permeabilities, Eq (15) is reduced to

$$\frac{\partial^2 h}{\partial x^2} + \frac{\partial^2 h}{\partial y^2} = 0 \tag{16}$$

Using the finite difference method of solution with the boundary conditions shown in Figure 3, hydrodynamic pore water pressures at various points along the inside and outside surfaces of the pile can be evaluated. The calculated pore water pressures can then be used to estimate the soil effective overburden pressures necessary for the pile bearing capacity determination.

The water rise inside the pile measured during the model test effectively reduces the external load acting on the pile by reducing the suction pressure on the inside soil surface. This therefore reduces the magnitude of the total head difference between the inside and outside soil surfaces. The net suction pressure acting on the inside soil surface, $p_{s\text{-}net}$, is expressed as.

$$p_{s\text{-}net} = p_s - H_w \gamma_w \tag{17}$$

where

$p_{s\text{-}net}$ = net suction pressure

p_s = applied suction pressure

H_w = water rise inside the pile above the outside water table

γ_w = unit weight of water

5.1.4 Sand Boiling

During the pile penetration into sand by suction, sand boiling can occur within the soil inside the pile when the upward seepage force exceeds the submerged weight of the soil. When the boiling condition occurs, the soil within the pile completely looses its strength and therefore allowing the soil to flow from outside into the pile inside. This will make it impossible for the pile to penetrate any further into the soil. When the hydraulic gradient between the pile tip and the inside soil surface equals to the critical hydraulic gradient, i_c, the sand boils. The critical hydraulic gradient is expressed as

$$i_c = \frac{\gamma_{sat}}{\gamma_w} - 1 \qquad (18)$$

where

i_c = critical hydraulic gradient

γ_{sat} = saturated unit weight of the soil

γ_w = unit weight of the water

The magnitude of the suction pressure to be applied inside the pile should be limited so that the hydraulic gradient remains less than the critical gradient. However, at the beginning of the pile installation a certain amount of initial penetration depth is required before any suction pressure is applied to prevent the soil boiling.

5.2 Analytical Solution

Incorporating the soil and pile behaviors described above, a computer program written in FORTRAN was developed to simulate the suction pile installation process. The analytical solution was then modified to calibrate the mobilized effective soil friction angle ratio α. It calculates the value of α that directly relates the measured pile penetration depth with the applied suction pressure under given conditions. Chapter 6 describes the details of the model test results and the calibration of α.

6. EXPERIMETAL RESULTS AND CALIBRATION

Eighteen different series of laboratory model tests were conducted with sand to simulate the pile installation procedure and to calibrate the mobilized effective soil friction angle ratio. The test series utilized different surcharge weights, initial pile penetration depths, and pile diameters. Each series consisted of 3 to 5 nearly identical tests to minimize any potential error. The details of the model tests are summarized in Table 2.

Pile type A in the table indicates the smaller diameter pile (0.415 ft.). The actual initial pile penetrations were not exactly identical to the values shown in the table due to the nature of manual penetration. The exact initial pile penetration for each test was however recorded as shown in Appendix 3. During the model testing, the pile penetration depth and the water rise inside the pile corresponding to the applied suction pressure were carefully

recorded and used together with the exact initial pile penetration depth for the calibration of α.

6.1 Experimental Results

Figure 4 shows the pile penetration vs. suction pressure relationship of Test 10 –A, i.e., first test of series 10. As expected, the pile penetration increased as the suction pressure increased. However, the pile penetration reached its peak at approximately 11 inches and further increase in suction pressure did not cause any additional pile penetration, indicating that the pile bearing capacity could not be overcome. As can be seen from the figure, near the end of the test an increase in suction pressure caused a sudden increase in pile penetration, indicating that sand boiling possibly occurred. Appendix-2 includes all pile penetration vs. suction pressure relationships that were used for the calibration of α.

6.2 Calibration of Mobilized Effective Soil Friction Angle Ratio

The experimental results have been used to calibrate the mobilized effective soil friction angle ratio α as described in section 5.2. The value of α was determined for each data point of the pile penetration vs. suction pressure relationship by matching the predicted pile penetration with that measured from the model test. Approximately 500 data points were analyzed and corresponding α values were obtained. Complete results of the analysis are included in Appendix 3 and Figure 5. As can be seen from the figure, α decreased as the pile penetration increased. In theory, α must be a unit at the pile penetration of zero. It must

also approach to zero as the pile penetration increases. Results indicate that these conditions are met.

Figure 6 shows the relationship between the suction pressure and α. As can be seen from the figure, α decreased in general as the suction pressure increased. This is in part due to the fact that relatively large suction pressures are required for larger pile penetrations. It is observed from the figure that the value of α approaches zero as the suction pressure increases continuously. This indicates that very little soil strength is needed at extremely large suction pressure to maintain the equilibrium state. The wide scatter of data points in the figure is primarily due to the effect of the initial pile penetration depth.

The calibrated values of α need to be expressed as a function of a non-dimensional term that includes all pertinent parameters associated with the suction pile installation in order for it to be used for the analysis of suction pile installation in the field. Following explains how the non-dimensional term has been obtained.

The pile penetration is resulted from the external loads including the self-weight of the pile, surcharge, and suction pressure. Therefore, the equivalent external pressure acting on top of the pile can be expressed as

$$p_t = p_s + \frac{F_b}{A} \tag{19}$$

where

p_t = equivalent external pressure

p_s = applied suction pressure

F_b = effective weight of the pile + effective weight of the surcharge

A = area of soil plug inside the pile

To include the effect of the pile penetration and to nondimensionalize the equivalent external pressure, the equivalent external pressure is divided by the effective overburden at the pile tip, i.e., the penetration depth.

$$X = \frac{p_t}{\gamma_b D_p} \tag{20}$$

where

X = normalized equivalent external pressure

γ_b = bouyant unit weight of the soil

D_p = penetration depth

The calibrated values of α are plotted with respect to the normalized equivalent external pressure as shown in Figure 7. As can be seen from the figure, all data points are grouped in two separate curves distinguished by the pile diameter. In general, α increases with the increase in the normalized equivalent external pressure. Again, α approaches to 1.0 as the normalized equivalent external pressure increases. α also approaches to zero as the normalized equivalent external pressure is reduced. The relationship must converge to the coordinate origin, since the coordinate origin represents the infinite pile penetration. These conditions completely satisfy the previously discussed upper and lower bounds of α. The values of α associated with the smaller diameter pile at a given normalized equivalent external pressure are smaller than those associated with the larger diameter pile, indicating that the pile aspect ratio also affects the value of α.

To eliminate the effect of the pile diameter in expressing the variation of α, the normalized equivalent external pressure has been further modified. By including the pile aspect ratio, i.e., the diameter to maximum penetration depth ratio (D/D_p-max), in the normalized equivalent external pressure, the variations of α can be combined into a single curve as shown in Figure 8. This variation of α includes all pertinent parameters associated with the suction pile installation. It can be expressed as a function of the dimensionless term and therefore may be used for the analysis of suction pile installation in the field. The relationship shown in Figure 8. can best be expressed with the following equation,

$$\alpha = C + \frac{A}{1 + BY^{E}} \tag{21}$$

where

$$Y = X\frac{D}{D_{p\text{-max}}}$$

A, B, C, and E = constants

Constants A, B, C, and E have been evaluated from the regression analysis with satisfying the previously described boundary values of α. The results indicate that the variation of α is expressed as

$$\alpha = 1 - \frac{1}{1 + 0.7071Y^{1.444}} \tag{22}$$

The solid line in Figure 9 indicates the variation of α according to Eq (22). This description of α is expected to be included in the analytical solution which can be used to control the suction pressure for successful installation of suction piles in the field.

7. CONCLUSIONS

Laboratory experiments on model suction piles indicate that suction is quite effective in driving piles into sand. However, the applied suction pressure magnitude is limited due to the possible soil instability within the pile, i.e., the boiling. It is also observed that the state of the soil inside the pile becomes loose due to the upward water flow caused by the suction pressure. Therefore, the conventional bearing capacity theories can not be used directly for the evaluation of the pile penetration. Mobilized effective soil friction angle ratio is therefore introduced to describe the average reduction in the soil internal friction angle. The mobilization effective soil friction angle ratio (α) is a function of the equivalent external pressure normalized by the effective soil overburden at the tip of the pile and the pile aspect ratio. The value of α decreases as the pile penetration and suction pressure increase. α approaches to zero as the pile penetration becomes very large, whereas it becomes 1.0 at zero pile penetration.

8. REFERENCES

1) Caquot, A., and Kerisel, J. (1953). "Sur le terme de surface dans le calcul des fondations en milieu pulverulent," *Proceedings*, Third International Conference on Soil Mechanics and Foundation Engineering, Zürich, Vol. I, pp. 336-337.

2) De Beer, F. E. (1970). "Experimental Determination of the Shape Factors and Bearing Capacity Factors of Sand," *Geotechnique*, Vol. 20, No. 4, pp. 387-411.

3) Hansen, J. B. (1970). "A Revised and Expended Formula for Bearing Capacity," Danish Geotechnical Institute, *Bulletin 28*, Copenhagen.

4) Prandtl, L. (1921). "Über die Eindringungsfestigkeit (Härte) plastischer Baustoffe und die Festigkeit von Schneiden," *Zeitschrift für angewandte Mathematik und Mechnik*, Vol. 1, No. 1, pp. 15-20.

5) Reissner, H. (1924). "Zum Erddruckproblem," *Proceedings*, First Intenational Congress of Applied Mechanics, Delft, pp. 295-311.

6) Vesic, A. S. (1973). "Analysis of Ultimate Loads of Shallow Foundations," Journal of the Soil Mechanics and Foundations Division, American Society of Civil Engineers, Vol. 99, No. SMI, pp 45-73.

Table 1. Details of Test Piles

Pile	Buoyant Weight (lbs)	Length (ft)	Outside Diameter (ft)	Thickness (inch)
A	9.6	5.0000	0.4150	0.265
B	13.2	5.0417	0.5342	0.245

Table 2. Details of Model Tests

Series	Pile Type	Effective Surcharge plus Pile Weight (lbs)	Approximate Initial Pile Penetration (inches)
1	A	48.8•	12.0
2	A	61.0	12.0
3	A	73.2	12.0
4	A	48.8	36.0
5	A	48.8	36.0
6	A	72.1	36.0
7	A	61.0	36.0
8	A	48.8	24.0
9	A	61.0	24.0
10	A	72.1	24.0
11	B	67.1	12.0
12	B	83.9	12.0
13	B	*	*
14	B	67.1	24.0
15	B	83.9	24.0
16	B	*	*
17	B	67.1	36.0
18	B	83.9	36.0

• indicates data not included in the analysis due to unusual behaviors.

Figure 1. Schematics of Pile and Vacuum System

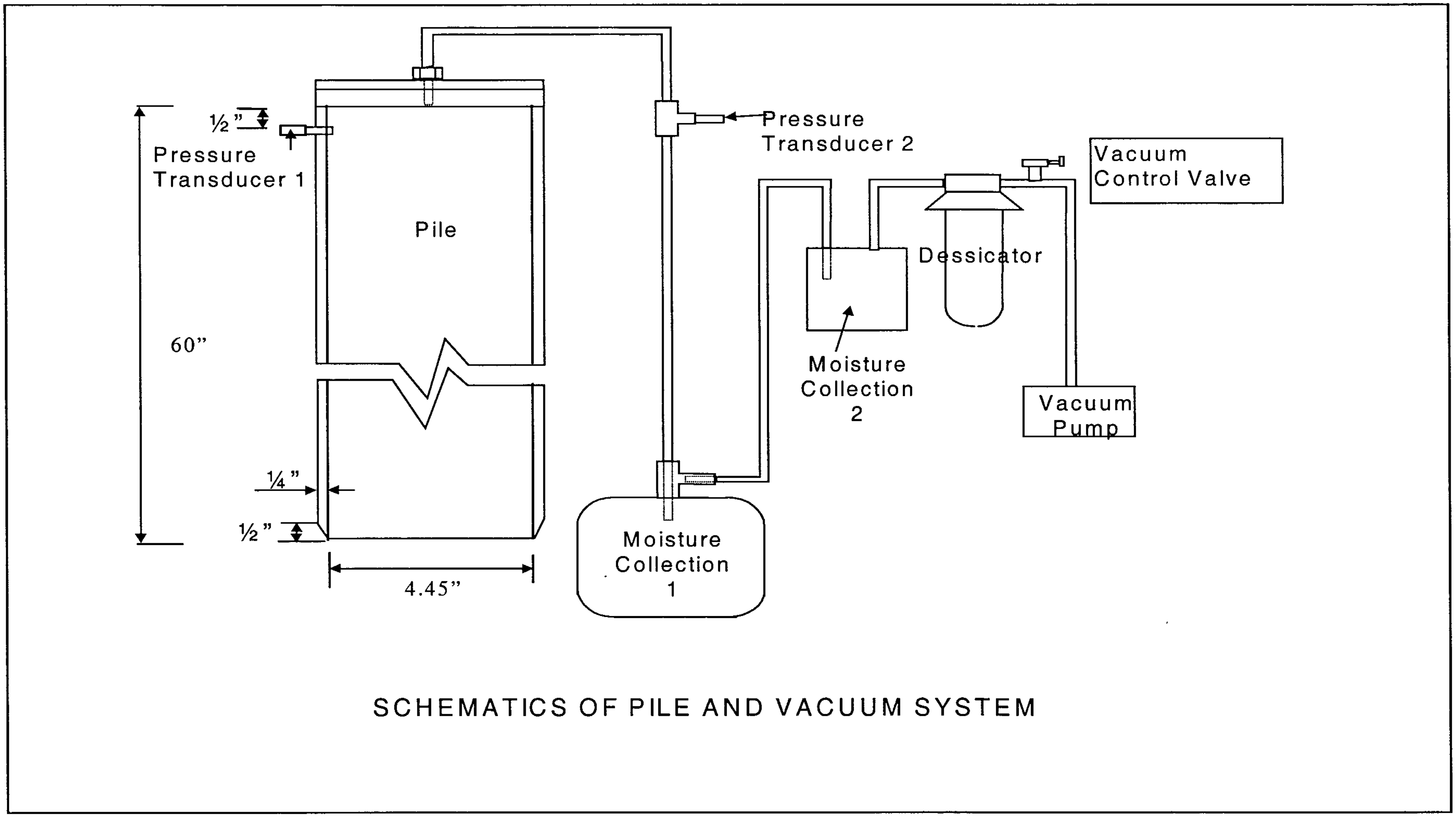


Figure 2. Schematics of Pile and Vacuum System

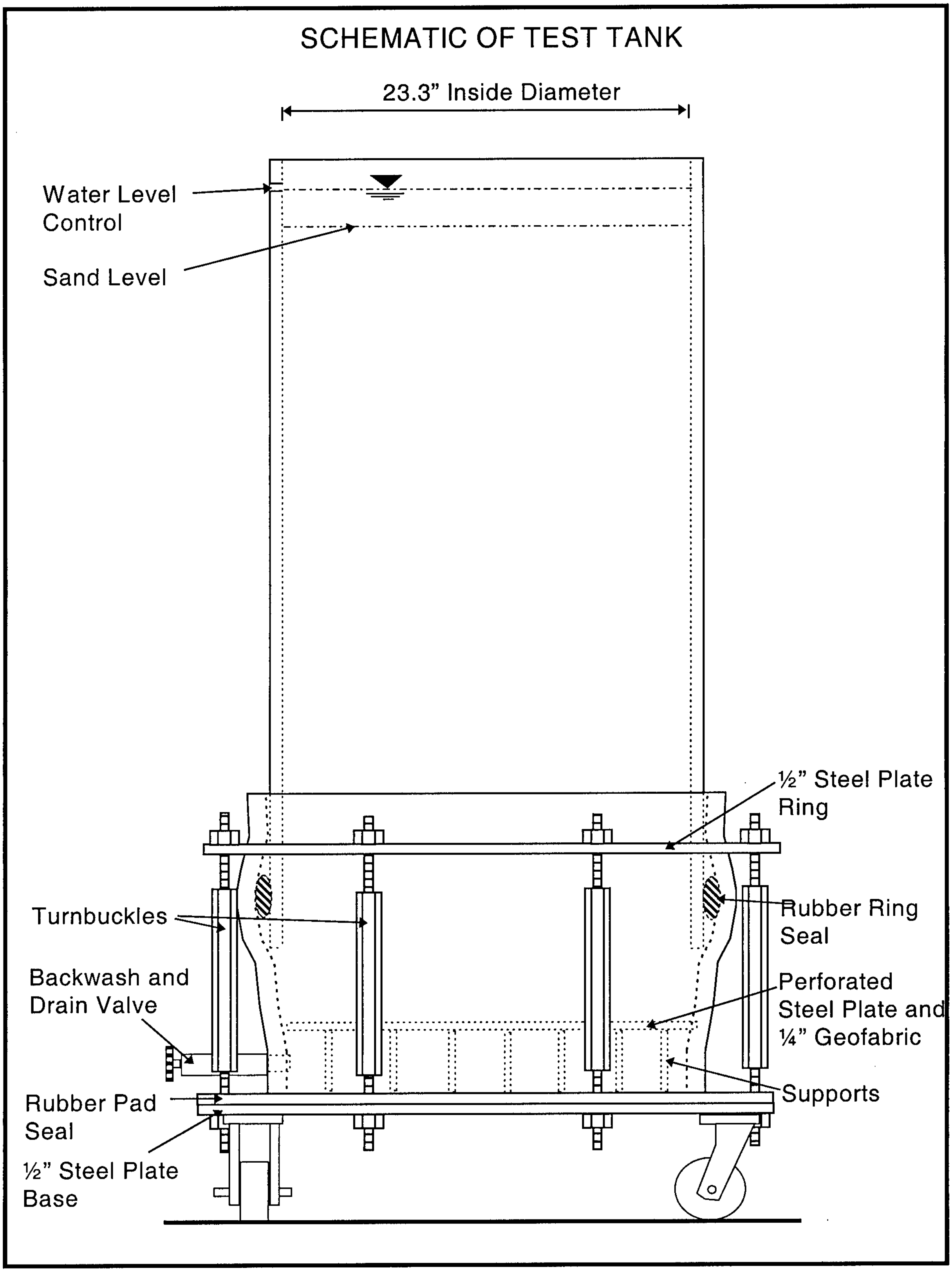


Figure 3. Schematics of Water Flow

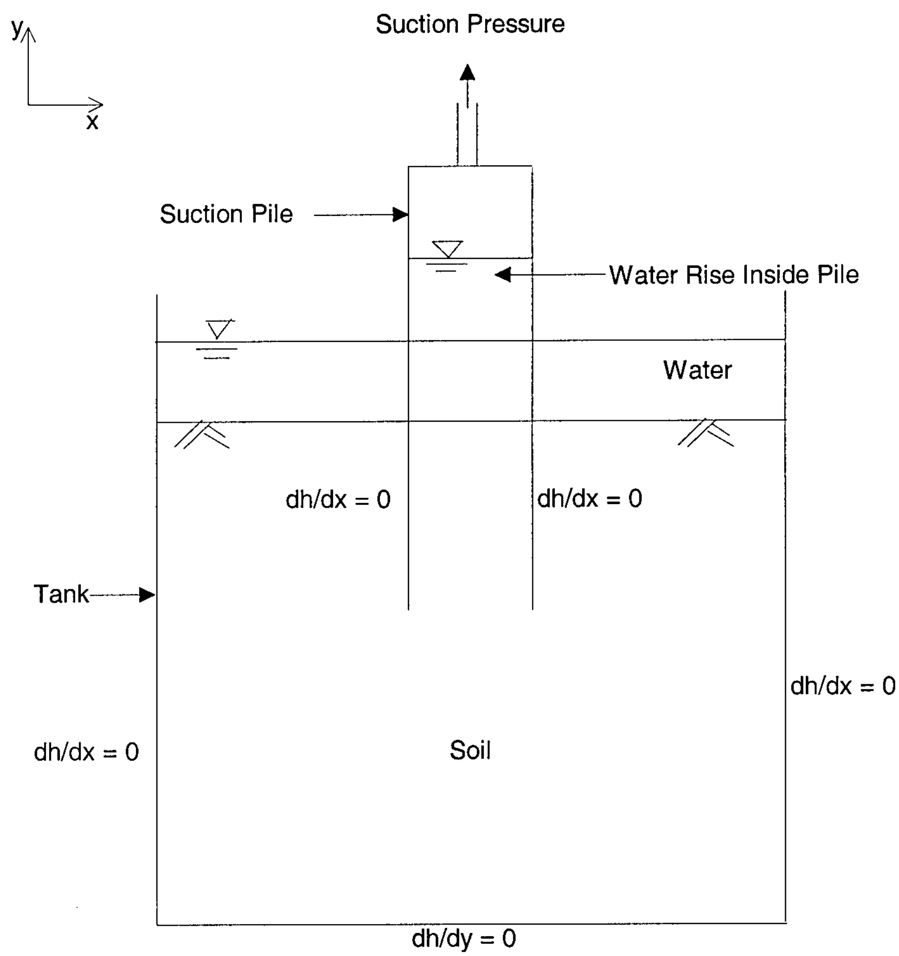


Figure 4. Suction Pressure vs. Pile Penetration (Series 10-A)

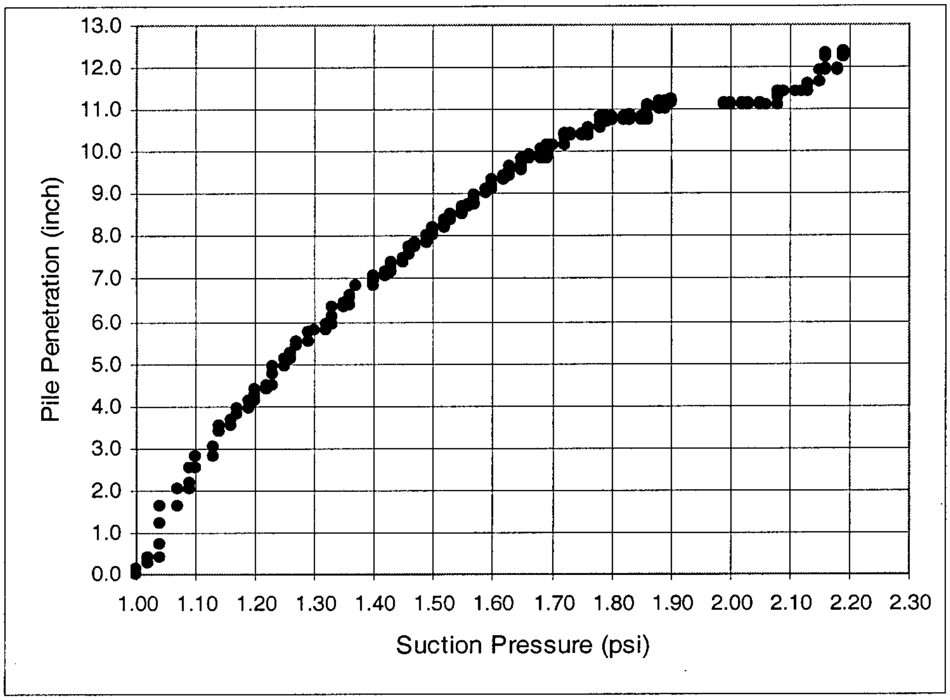


Figure 5. α vs. Pile Penetration (D_p)

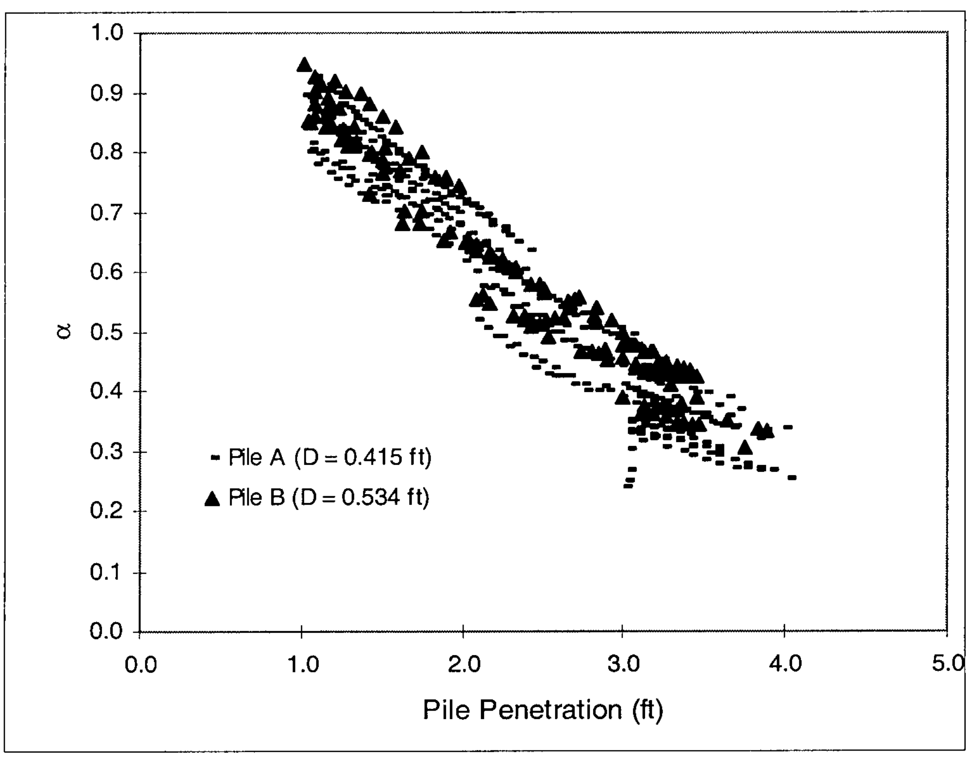


Figure 6. α vs. Suction Pressure (p_s)

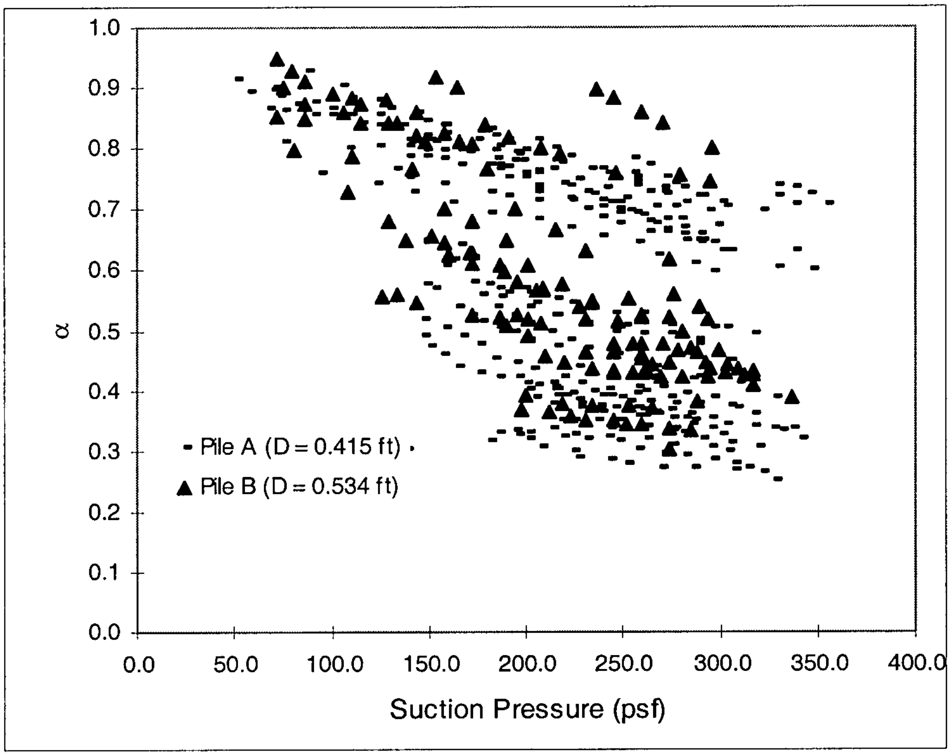


Figure 7. α vs. Normalized Equivalent External Pressure

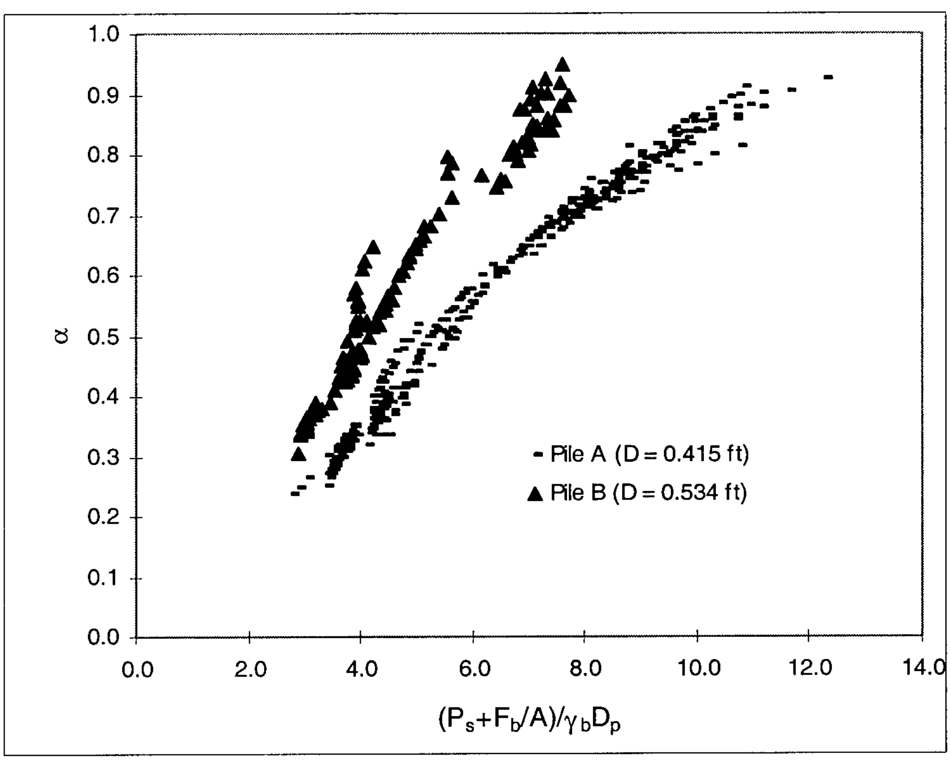
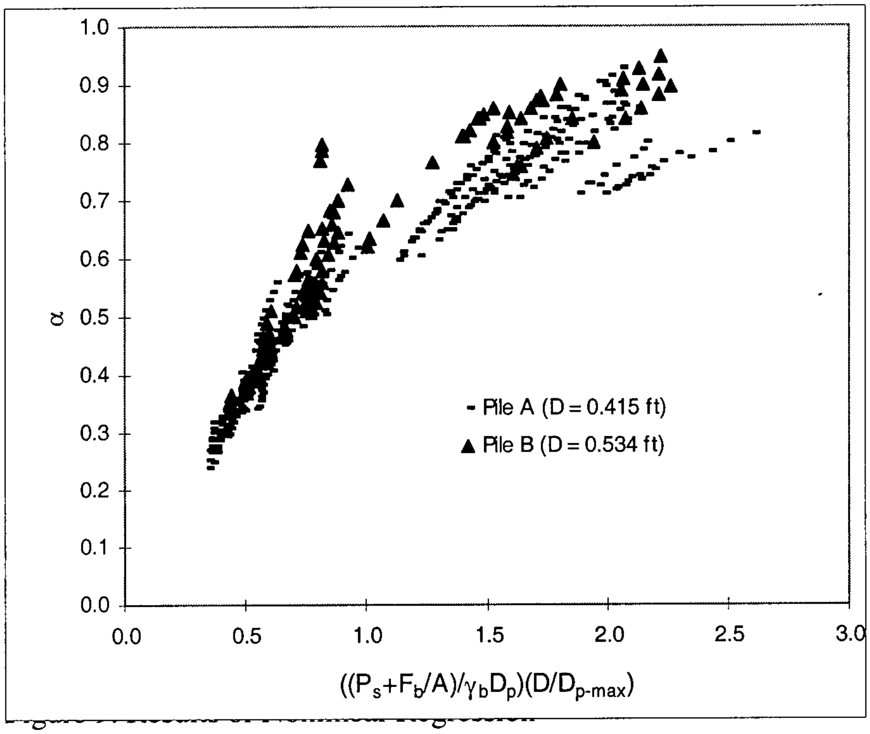
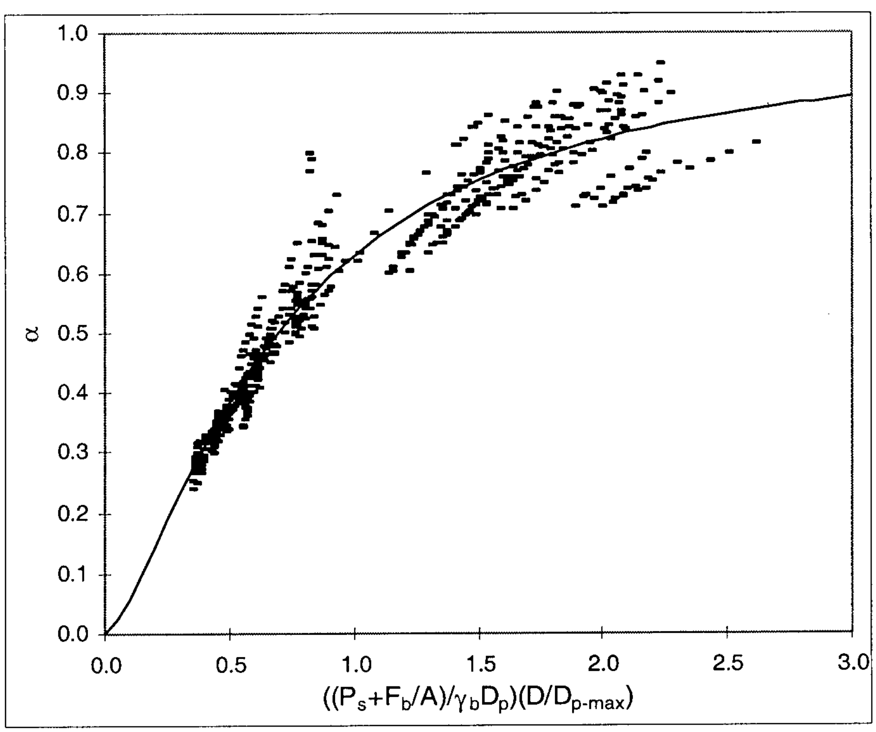


Figure 8. α vs. Normalized Equivalent External Pressure Including the Pile Aspect Ratio





APPENDIX – 1. PHOTOS OF TEST APPARATUS

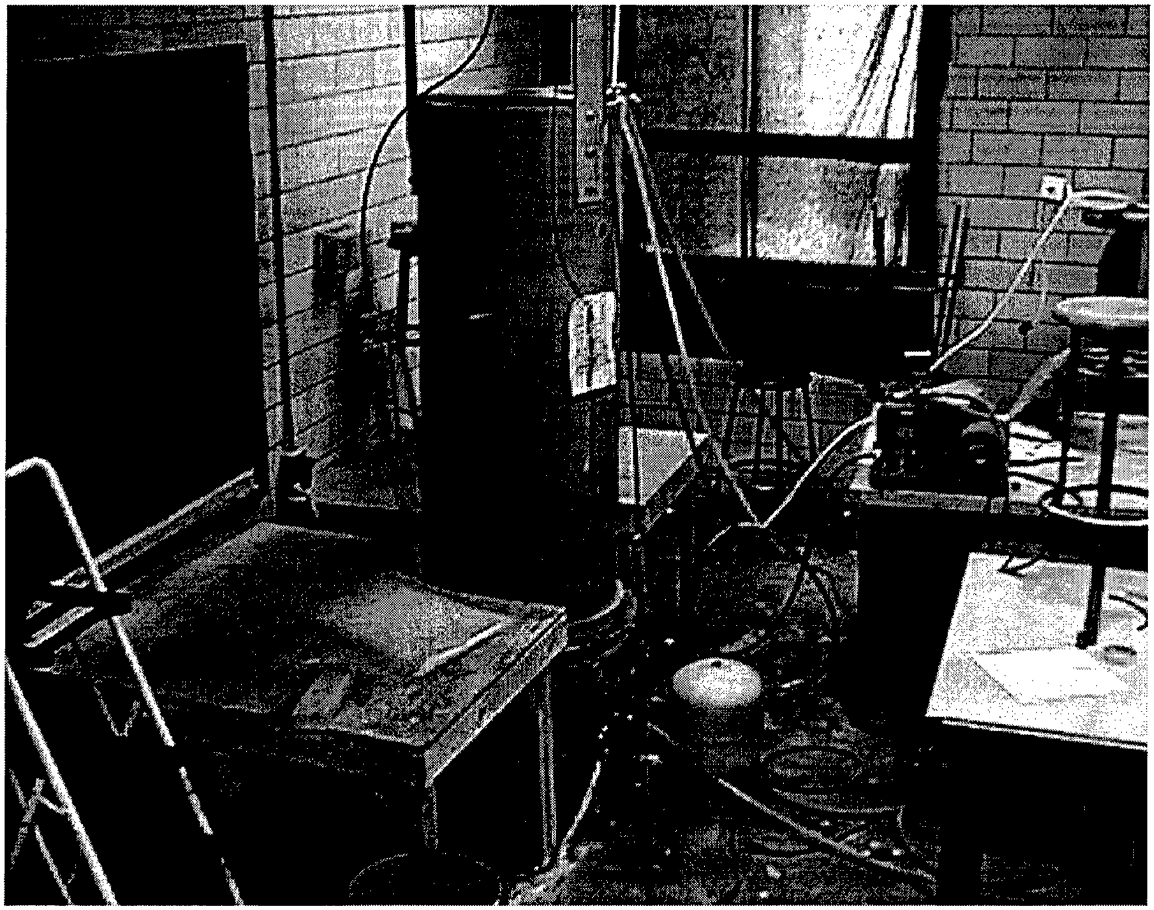


Fig – 1 Suction Pile Model Test Set-up

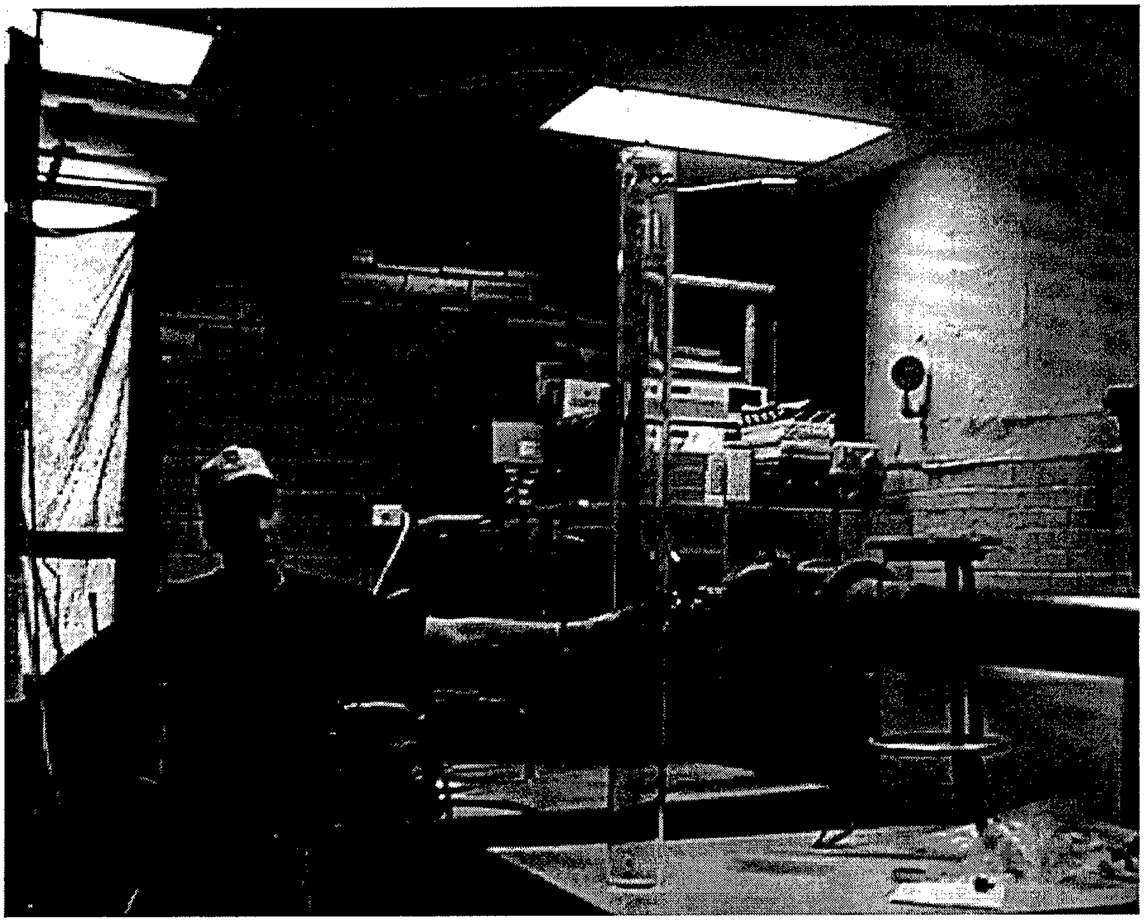


Fig – 2 Model Suction Pile

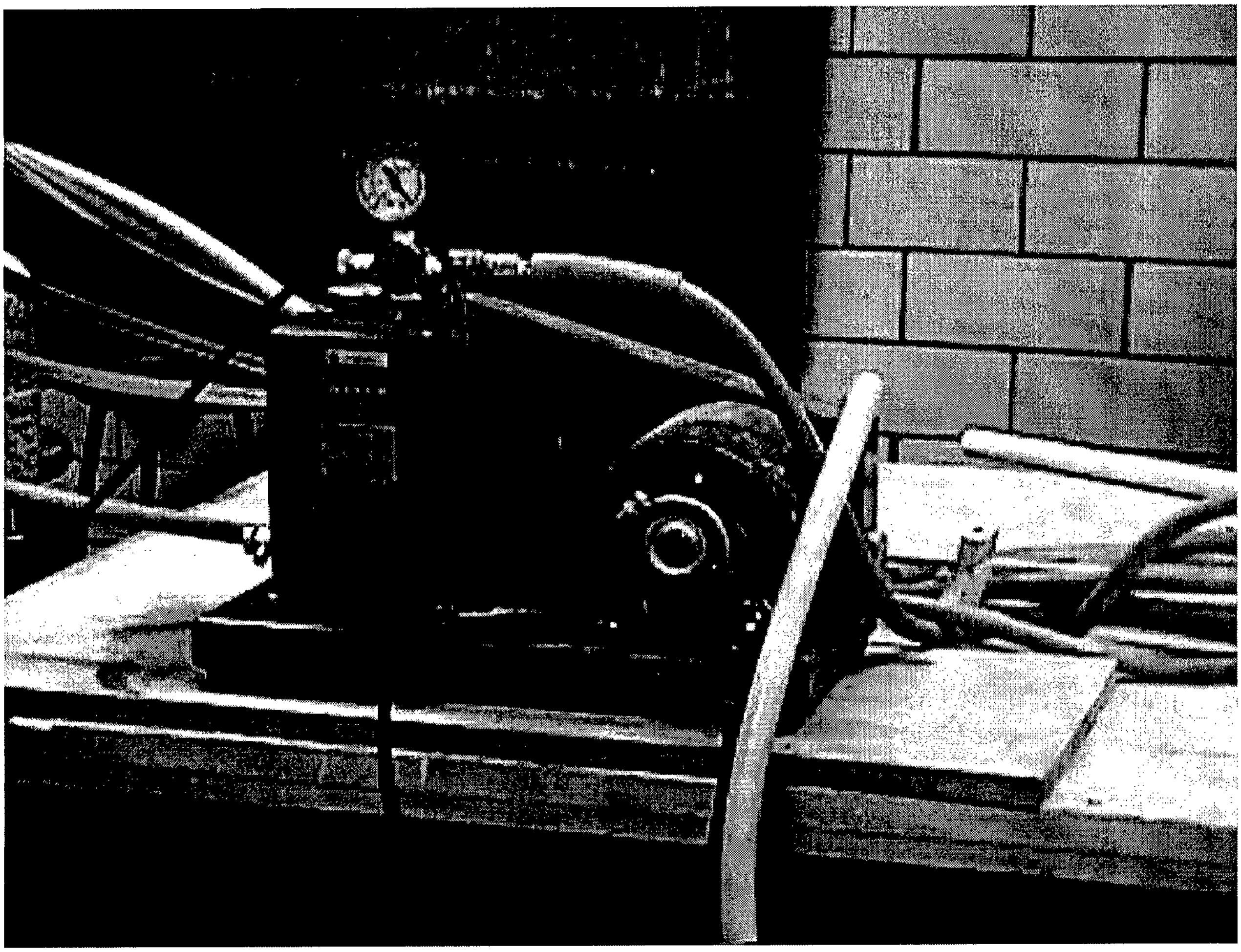


Fig – 3 Vacuum Pump

Fig – 4 High Pressure Moisture Collection Tank

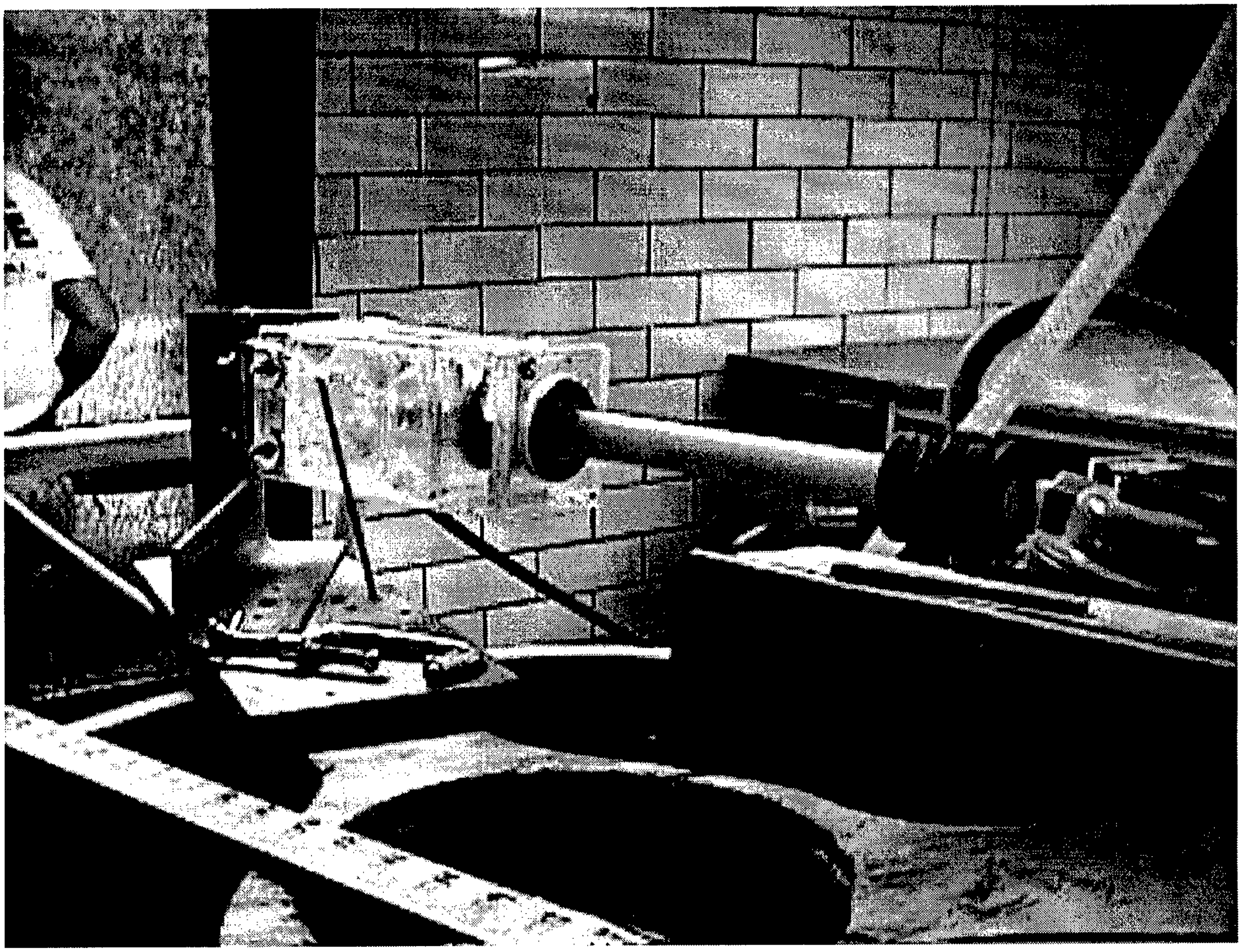


Fig – 5 Penetration Measurement Device

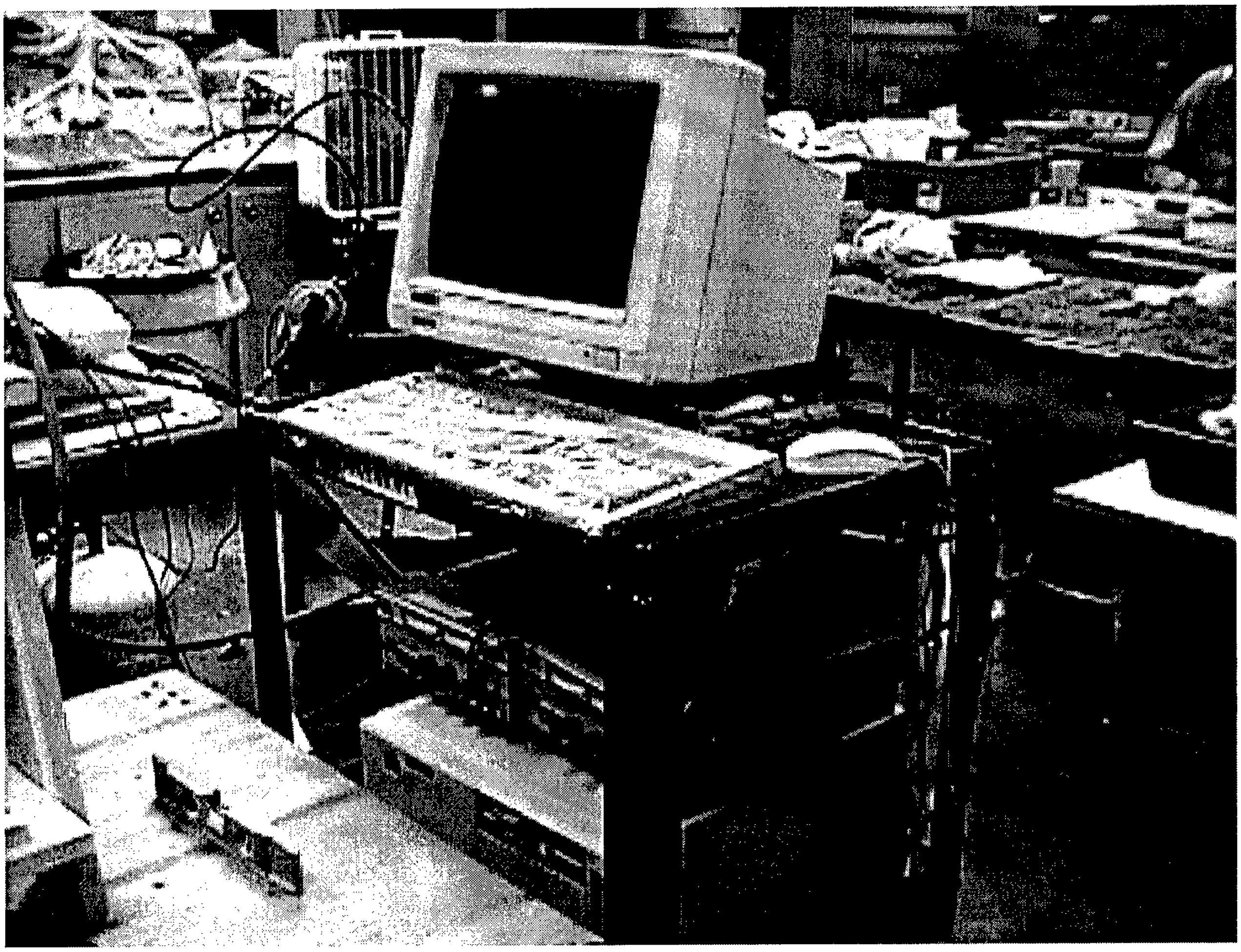


Fig – 6 Digital Data Acquisition System

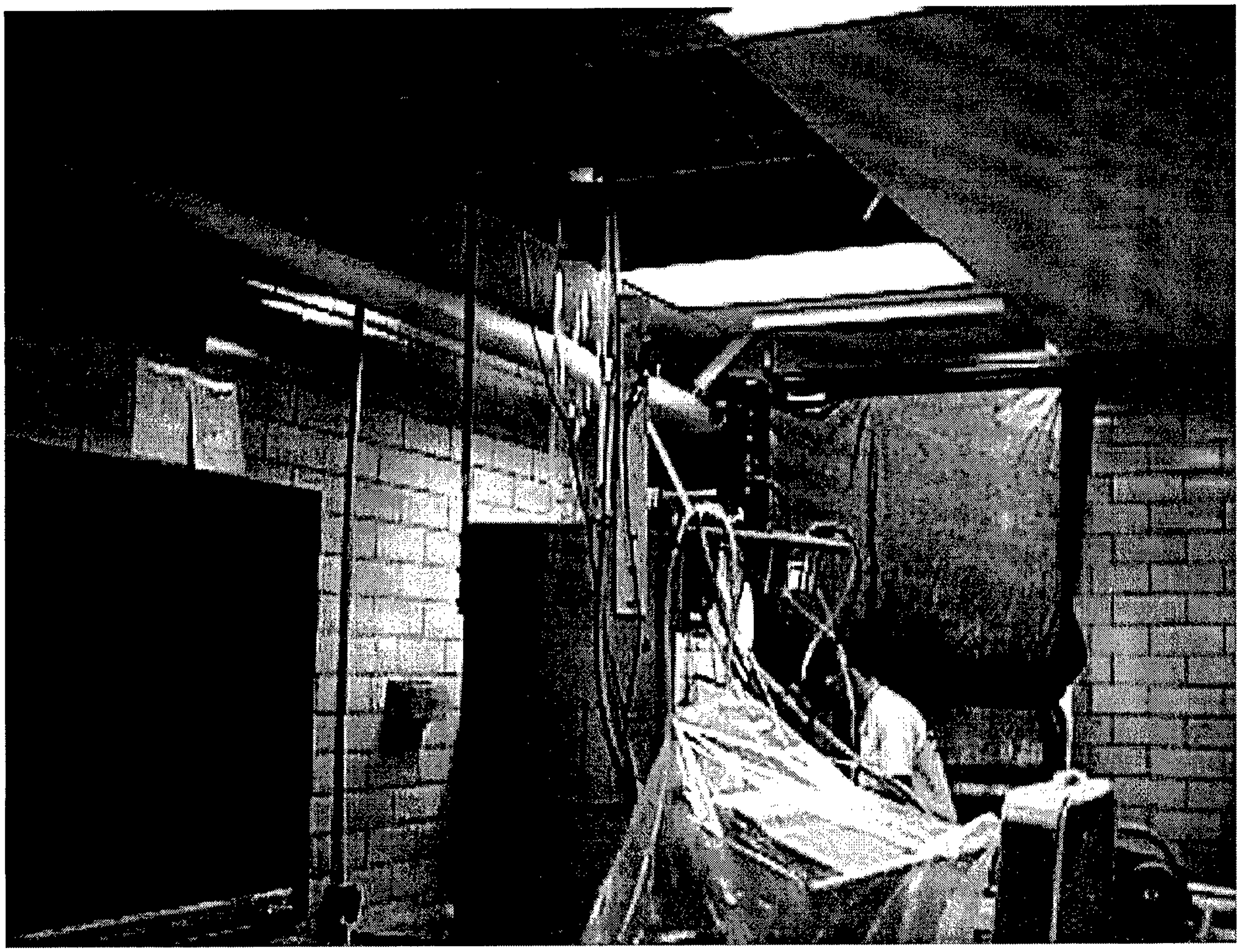


Fig – 7 Set-up Before Testing

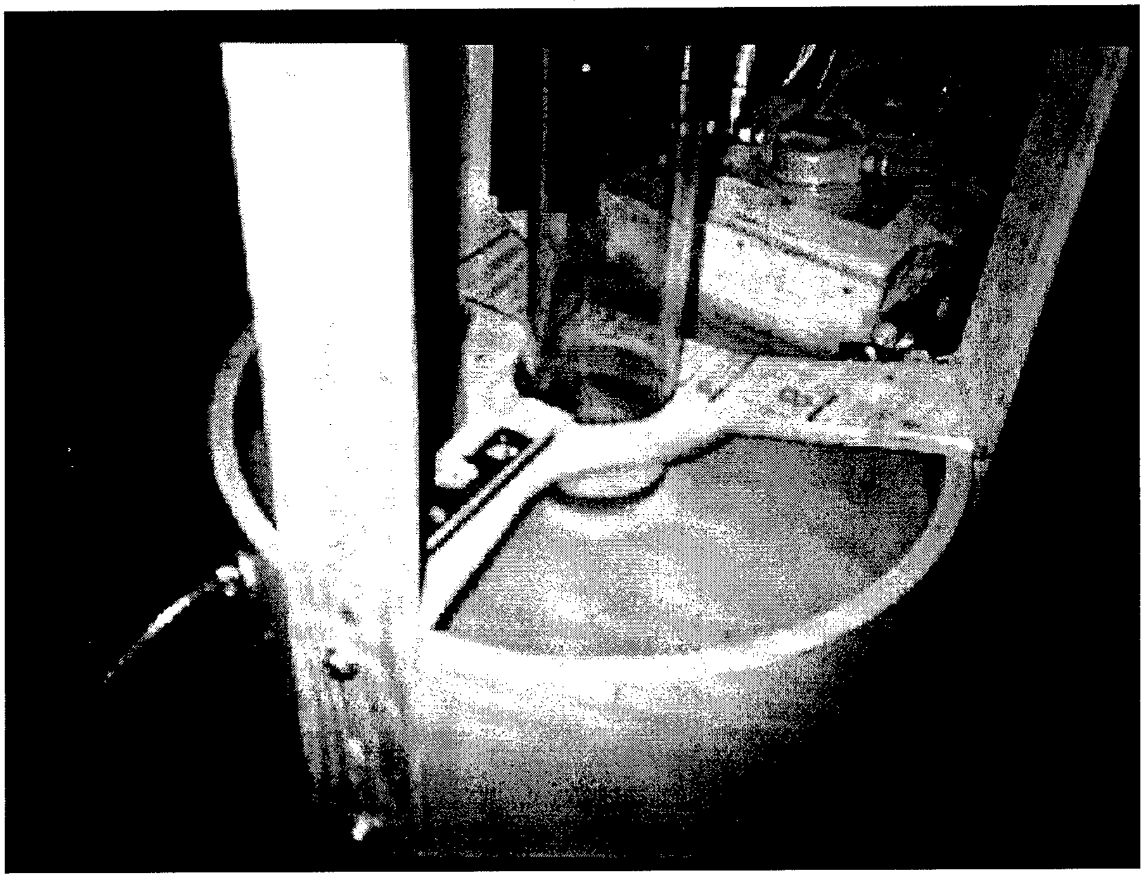


Fig – 8 Top View of Model Test Set-up

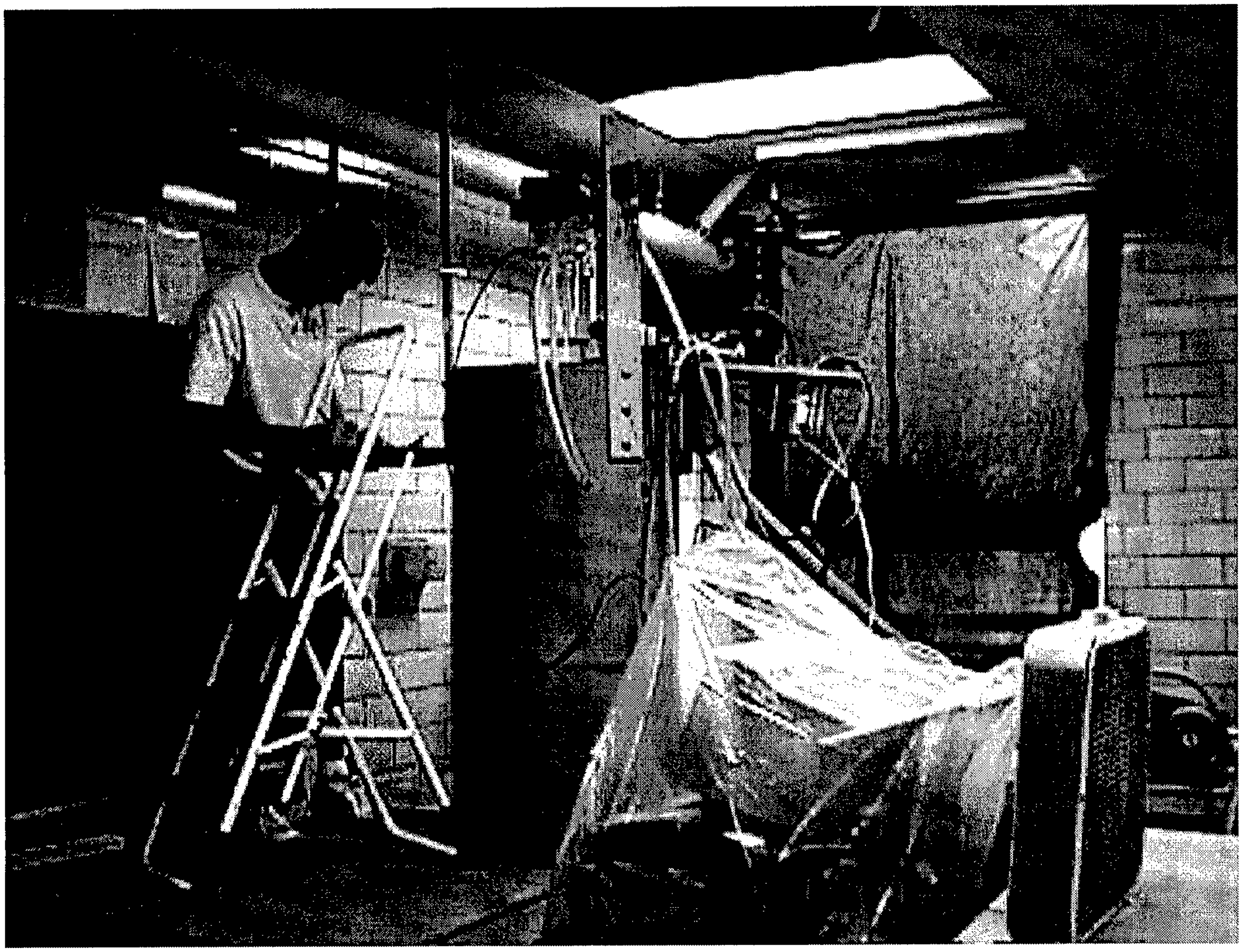


Fig – 9 Pile Being Penetrated

APPENDIX – 2. EXPERIMENTAL RESULTS

TABLE OF FIGURES

Figure I1 Suction Pressure vs. Pile Penetration (Series 1 – B)

Figure I2 Suction Pressure vs. Pile Penetration (Series 1 – C)

Figure I3 Suction Pressure vs. Pile Penetration (Series 1 – E)

Figure I4 Suction Pressure vs. Pile Penetration (Series 2 – A)

Figure I5 Suction Pressure vs. Pile Penetration (Series 2 – B)

Figure I6 Suction Pressure vs. Pile Penetration (Series 2 – C)

Figure I7 Suction Pressure vs. Pile Penetration (Series 2 – D)

Figure I8 Suction Pressure vs. Pile Penetration (Series 2 – E)

Figure I9 Suction Pressure vs. Pile Penetration (Series 2 – F)

Figure I10 Suction Pressure vs. Pile Penetration (Series 3 – A)

Figure I11 Suction Pressure vs. Pile Penetration (Series 3 – B)

Figure I12 Suction Pressure vs. Pile Penetration (Series 3 – C)

Figure I13 Suction Pressure vs. Pile Penetration (Series 3 – D)

Figure I14 Suction Pressure vs. Pile Penetration (Series 4 – B)

Figure I15 Suction Pressure vs. Pile Penetration (Series 4 – C)

Figure I16 Suction Pressure vs. Pile Penetration (Series 4 – D)

Figure I17 Suction Pressure vs. Pile Penetration (Series 4 – E)

Figure I18 Suction Pressure vs. Pile Penetration (Series 5 – B)

Figure I19 Suction Pressure vs. Pile Penetration (Series 5 – C)

Figure I20 Suction Pressure vs. Pile Penetration (Series 5 – D)

Figure I21 Suction Pressure vs. Pile Penetration (Series 6 – A)

Figure I22 Suction Pressure vs. Pile Penetration (Series 6 – B)

Figure I23 Suction Pressure vs. Pile Penetration (Series 6 – C)

Figure I24 Suction Pressure vs. Pile Penetration (Series 6 – D)

Figure I25 Suction Pressure vs. Pile Penetration (Series 7 – A)

Figure I26 Suction Pressure vs. Pile Penetration (Series 7 – B)

Figure I27 Suction Pressure vs. Pile Penetration (Series 7 – C)

Figure I28 Suction Pressure vs. Pile Penetration (Series 7 – D)

Figure I29 Suction Pressure vs. Pile Penetration (Series 8 – B)

Figure I30 Suction Pressure vs. Pile Penetration (Series 8 – C)

Figure I31 Suction Pressure vs. Pile Penetration (Series 9 – A)

Figure I32 Suction Pressure vs. Pile Penetration (Series 9 – C)

Figure I33 Suction Pressure vs. Pile Penetration (Series 9 – D)

Figure I34 Suction Pressure vs. Pile Penetration (Series 10 – A)

Figure I35 Suction Pressure vs. Pile Penetration (Series 10 – B)

Figure I36 Suction Pressure vs. Pile Penetration (Series 10 – E)

Figure I37 Suction Pressure vs. Pile Penetration (Series 11 – A)

Figure I38 Suction Pressure vs. Pile Penetration (Series 11 – B)

Figure I39 Suction Pressure vs. Pile Penetration (Series 11 – D)

Figure I40 Suction Pressure vs. Pile Penetration (Series 12 – B)

Figure I41 Suction Pressure vs. Pile Penetration (Series 12 – C)

Figure I42 Suction Pressure vs. Pile Penetration (Series 12 – D)

Figure I43 Suction Pressure vs. Pile Penetration (Series 14 – A)

Figure I44 Suction Pressure vs. Pile Penetration (Series 14 – B)

Figure I45 Suction Pressure vs. Pile Penetration (Series 15 – A)

Figure I46 Suction Pressure vs. Pile Penetration (Series 15 – C)

Figure I47 Suction Pressure vs. Pile Penetration (Series 15 – D)

Figure I48 Suction Pressure vs. Pile Penetration (Series 17 – A)

Figure I49 Suction Pressure vs. Pile Penetration (Series 17 – B)

Figure I50 Suction Pressure vs. Pile Penetration (Series 18 – A)

Figure I51 Suction Pressure vs. Pile Penetration (Series 18 – B)

Figure I52 Suction Pressure vs. Pile Penetration (Series 18 – C)

Figure I53 Suction Pressure vs. Pile Penetration (Series 18 – E)

Figure I1. Suction Pressure vs. Pile Penetration (Series 1 - B)

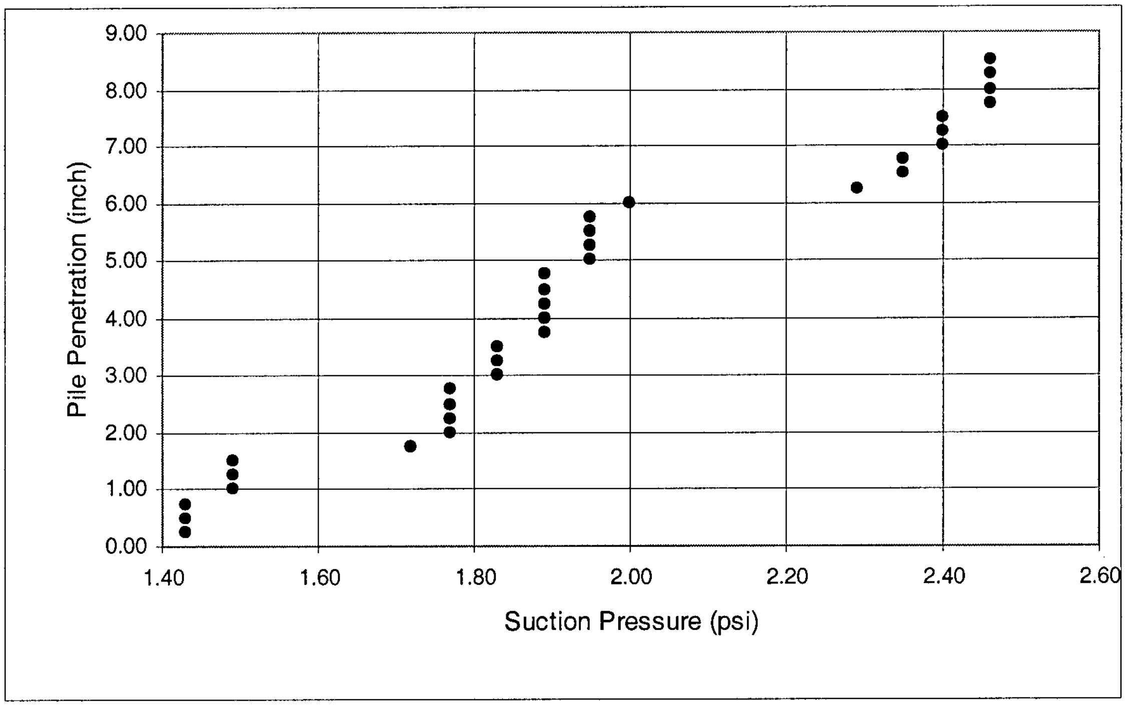


Figure I2. Suction Pressure vs. Pile Penetration (Series 1 - C)

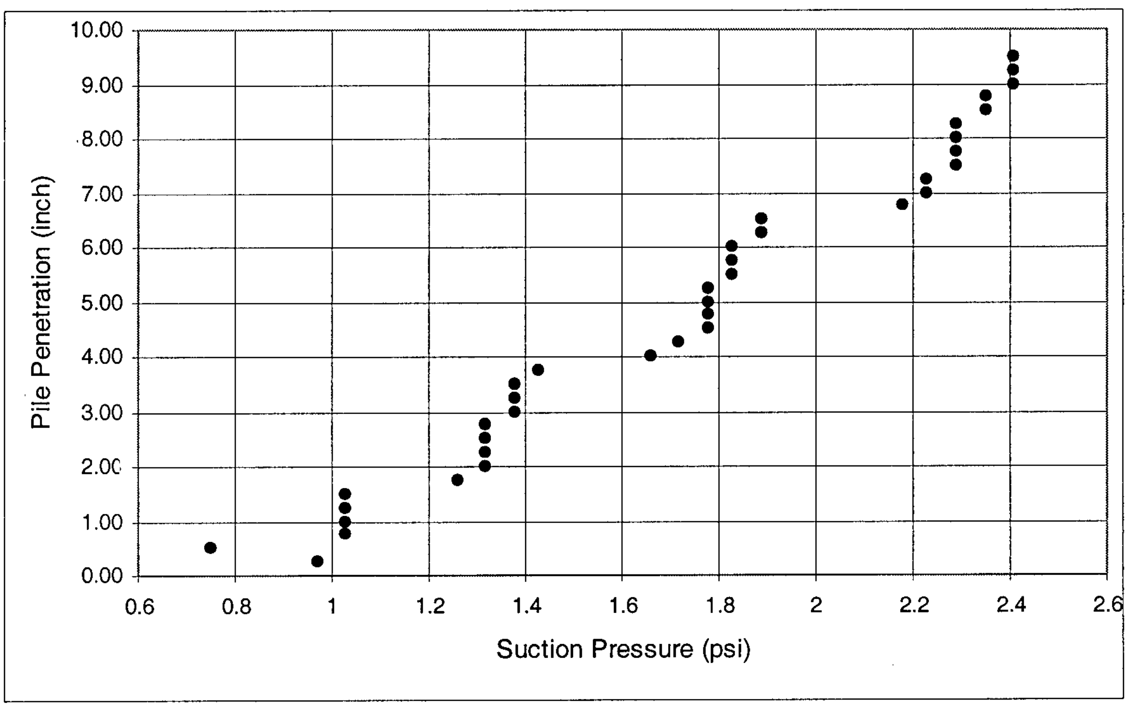


Figure I3. Suction Pressure vs. Pile Penetration (Series 1 - E)

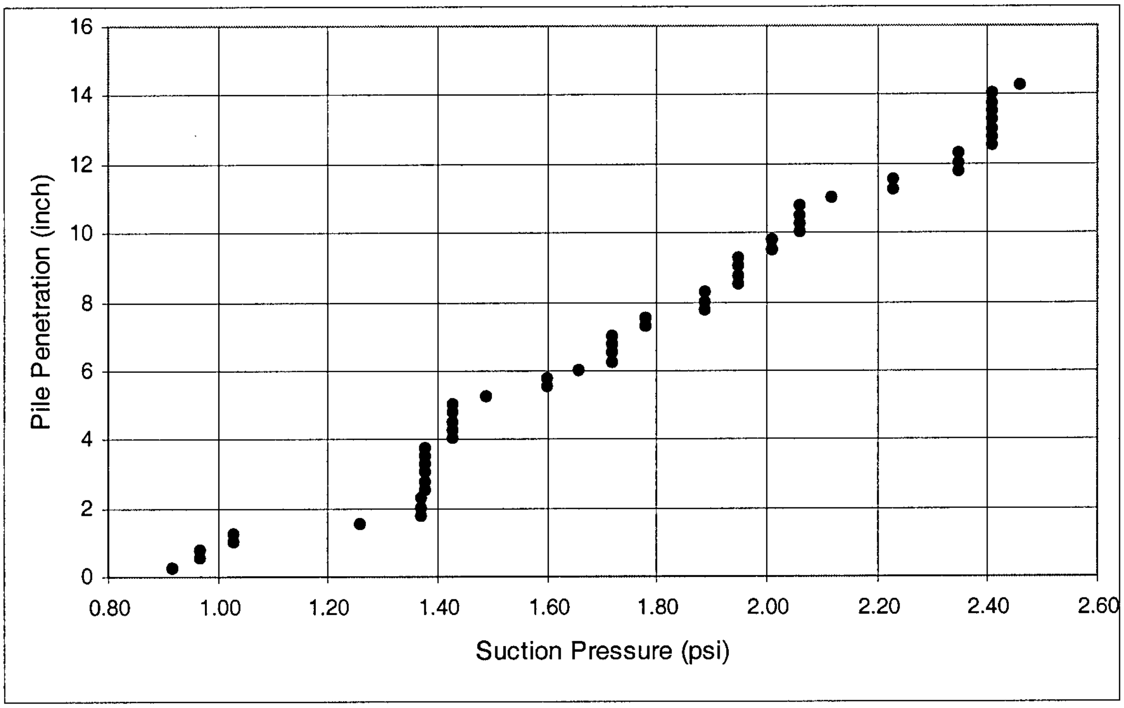


Figure I4. Suction Pressure vs. Pile Penetration (Series 2 - A)

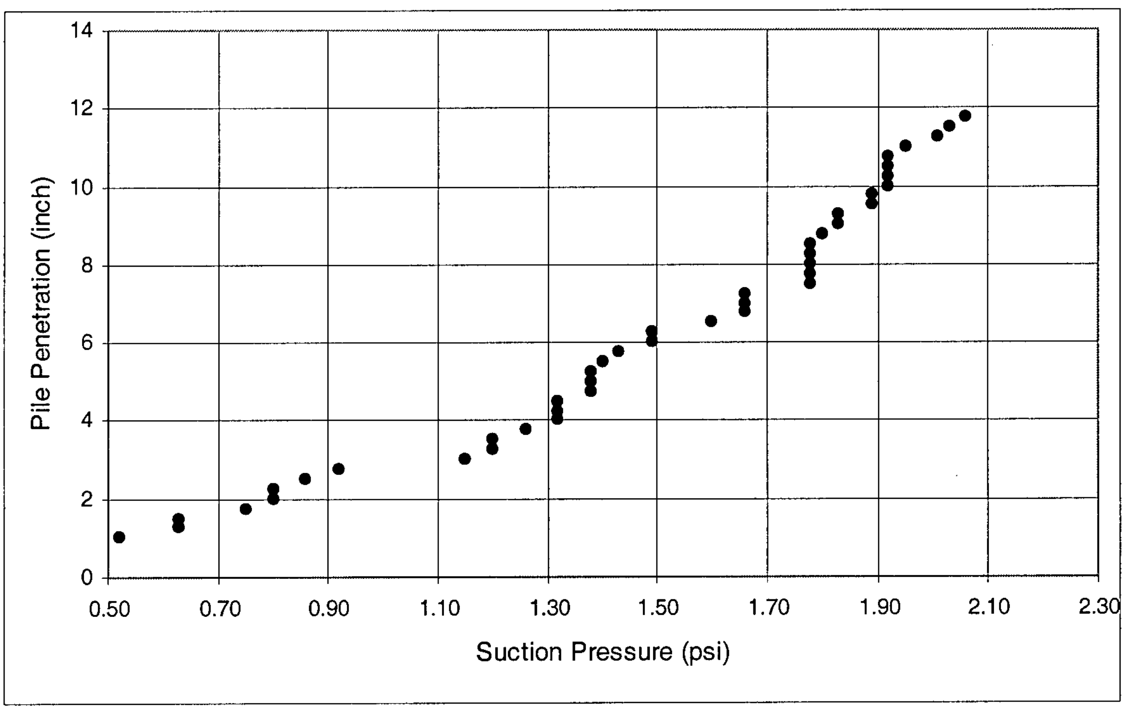


Figure I5. Suction Pressure vs. Pile Penetration (Series 2 - B)

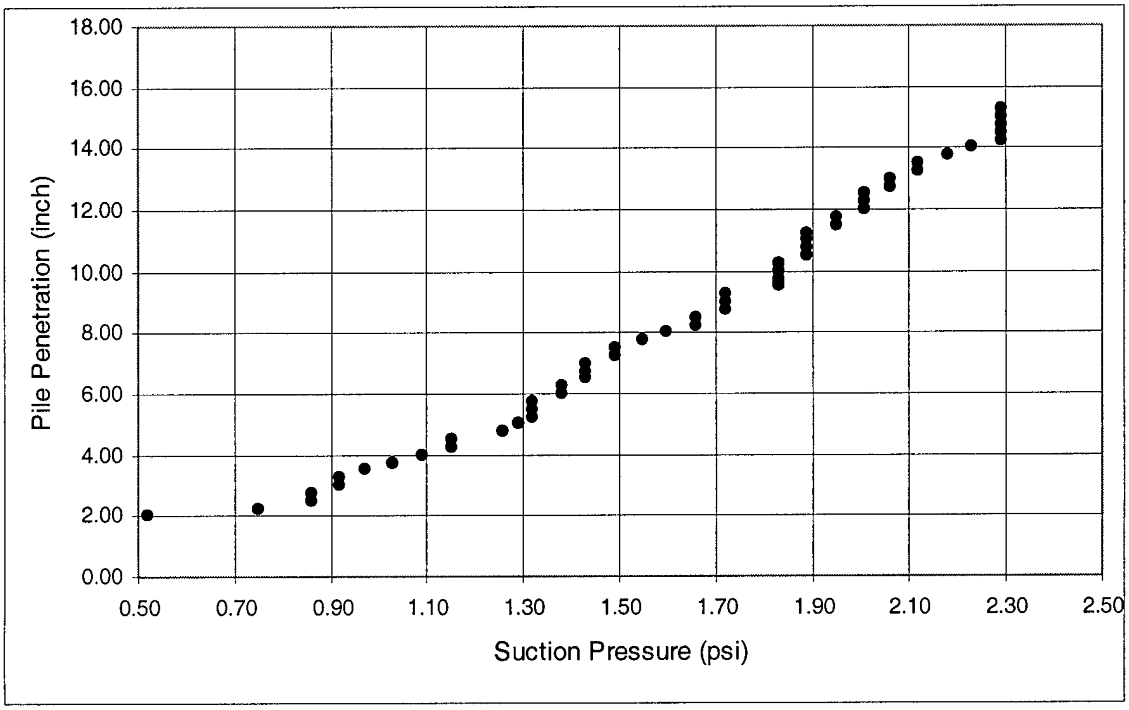


Figure I6. Suction Pressure vs. Pile Penetration (Series 2 - C)

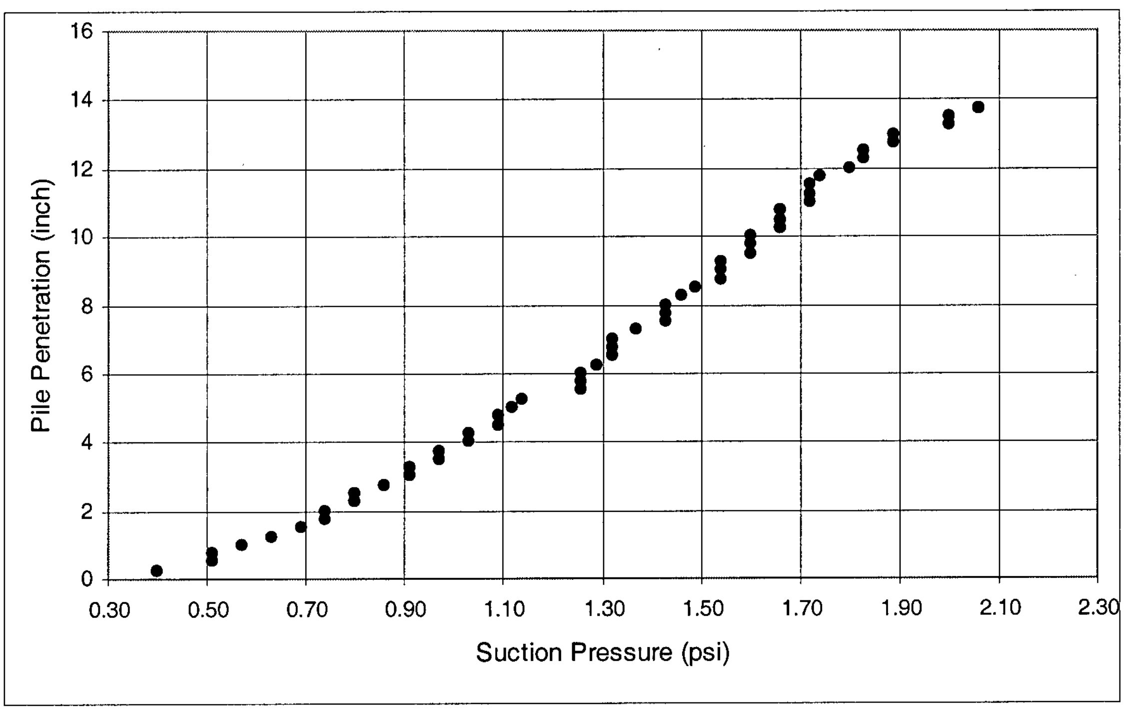


Figure I7. Suction Pressure vs. Pile Penetration (Series 2 - D)

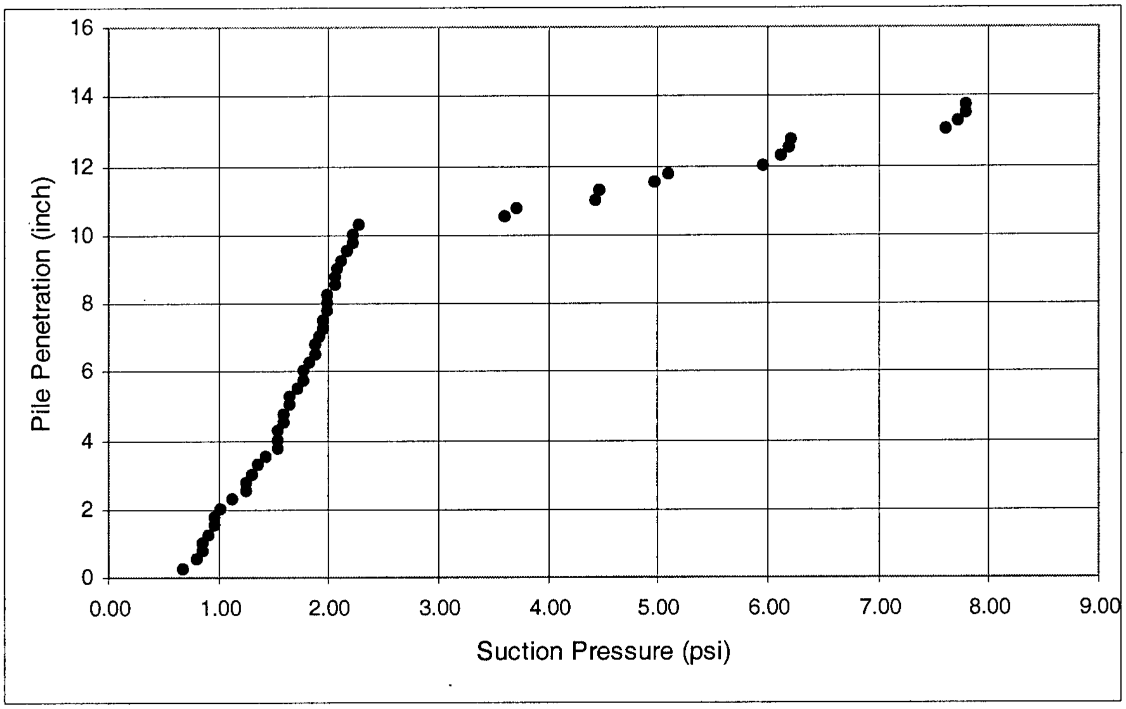


Figure I8. Suction Pressure vs. Pile Penetration (Series 2 - E)

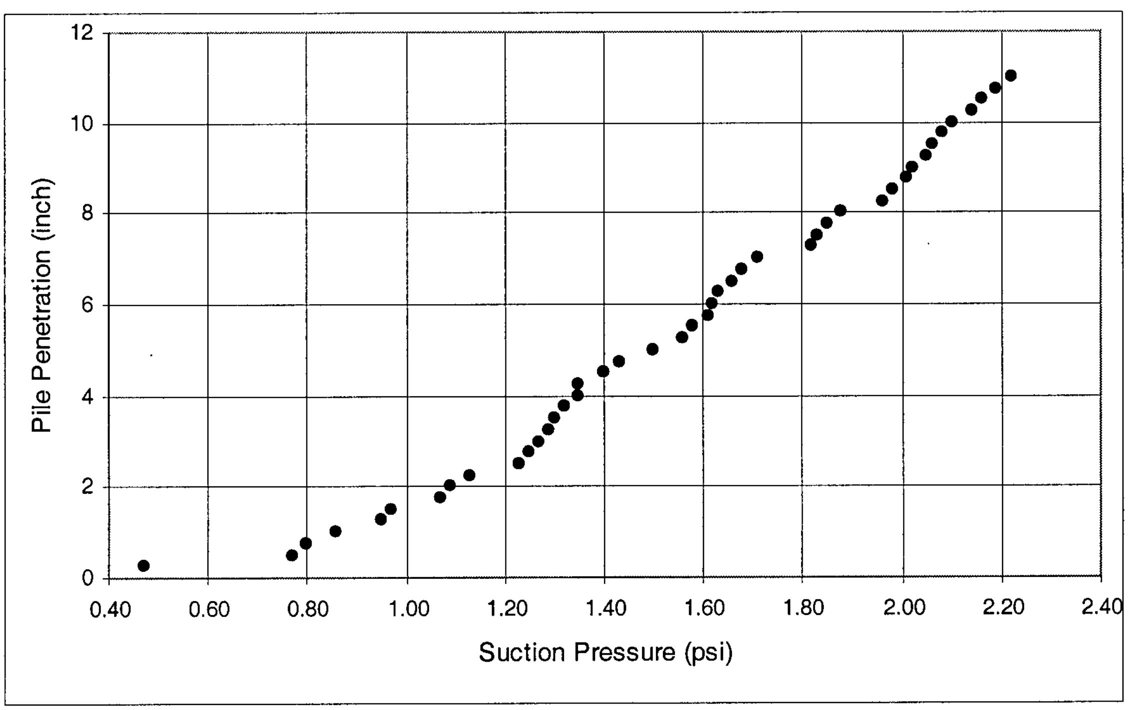


Figure I9. Suction Pressure vs. Pile Penetration (Series 2 - F)

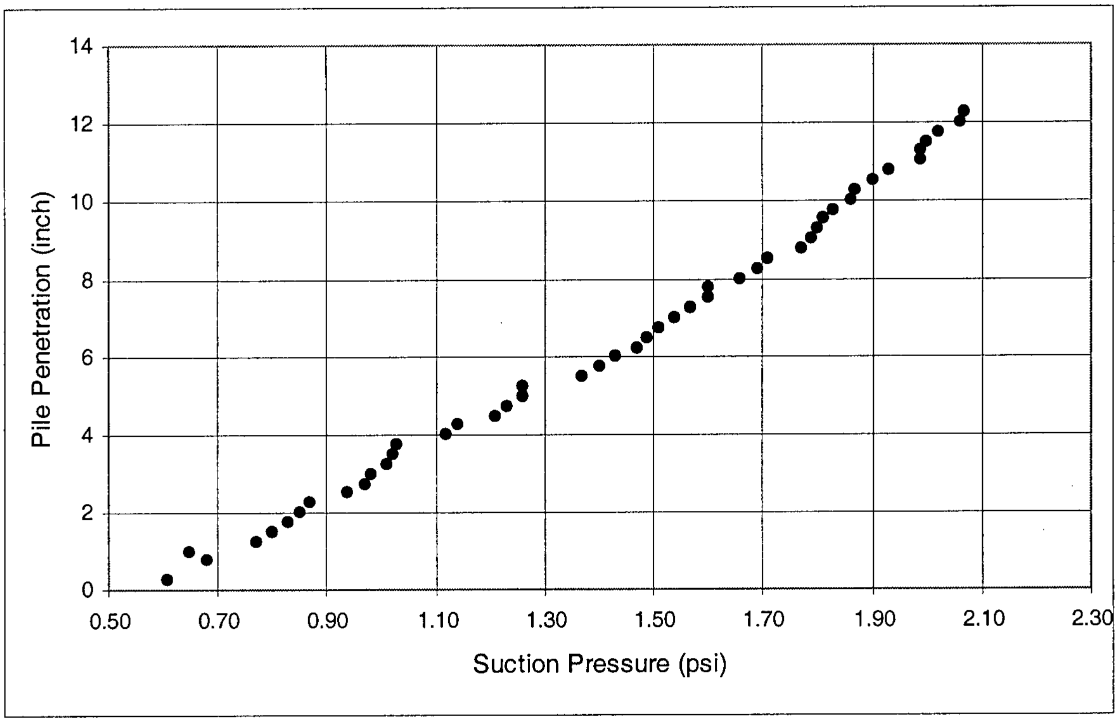


Figure I10. Suction Pressure vs. Pile Penetration (Series 3 - A)

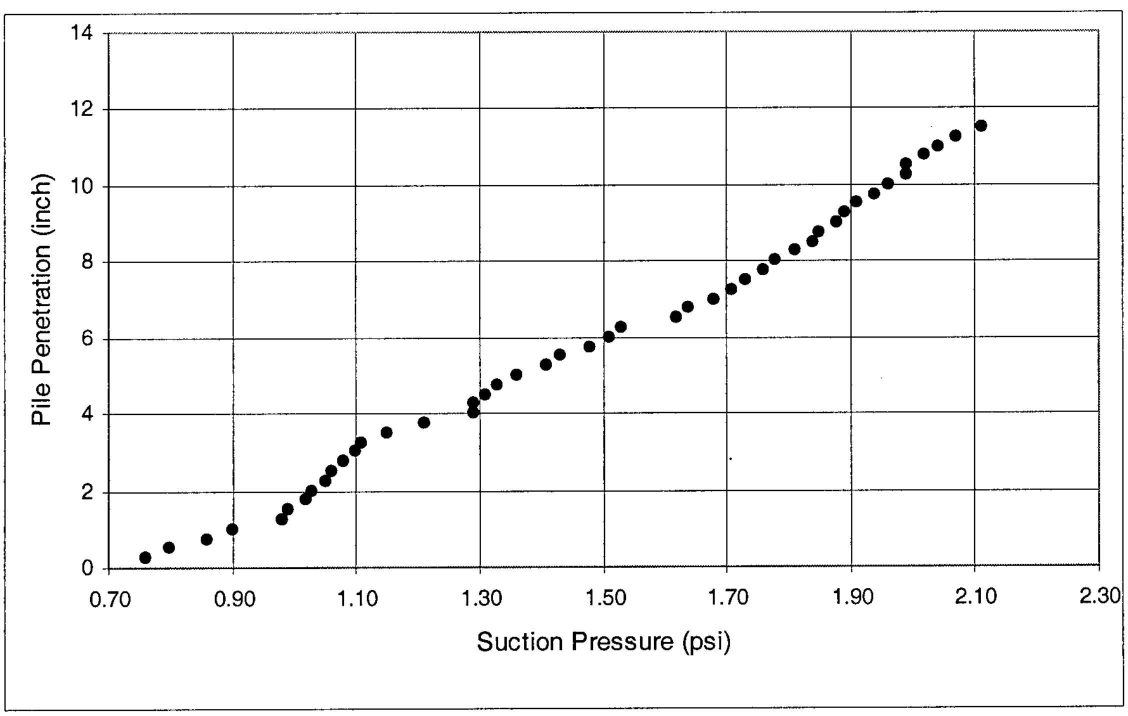


Figure I11. Suction Pressure vs. Pile Penetration (Series 3 - B)

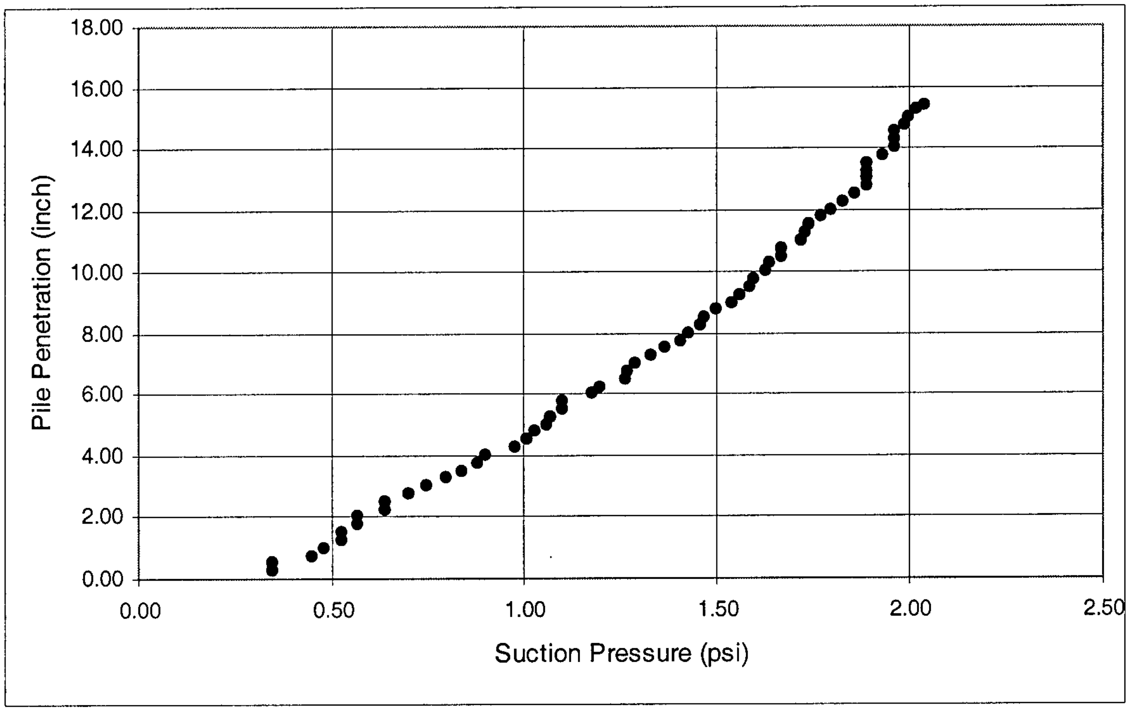


Figure I12. Suction Pressure vs. Pile Penetration (Series 3 - C)

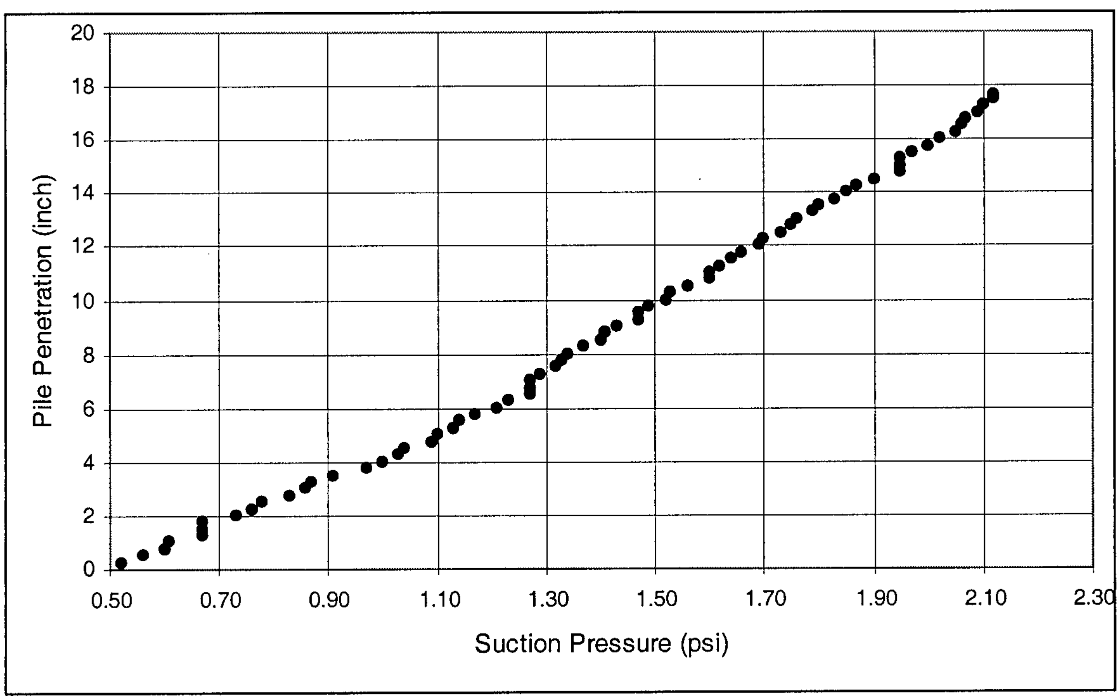


Figure I13. Suction Pressure vs. Pile Penetration (Series 3 - D)

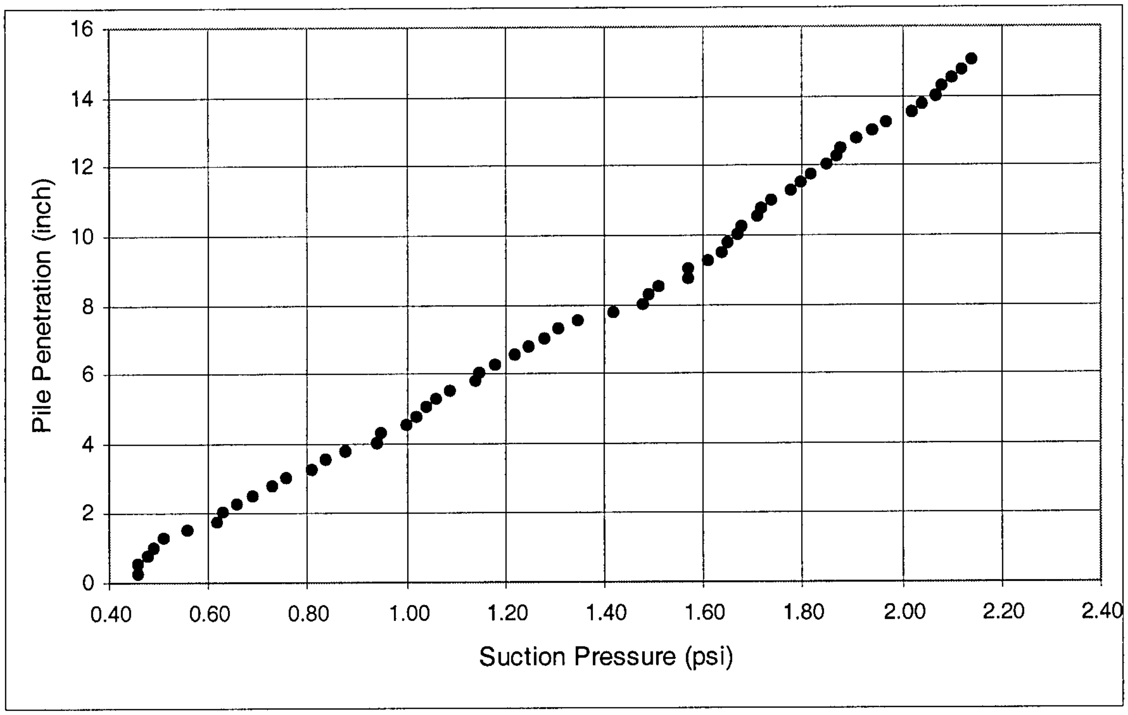


Figure I14. Suction Pressure vs. Pile Penetration (Series 4 - B)

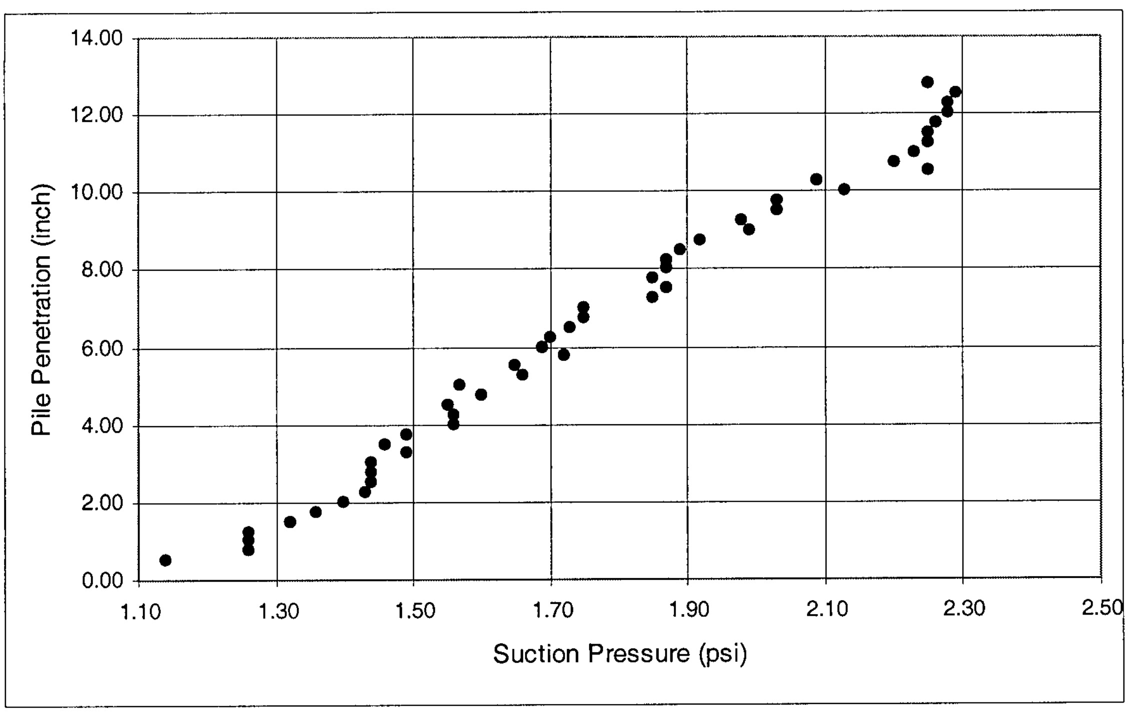


Figure I15. Suction Pressure vs. Pile Penetration (Series 4 - C)

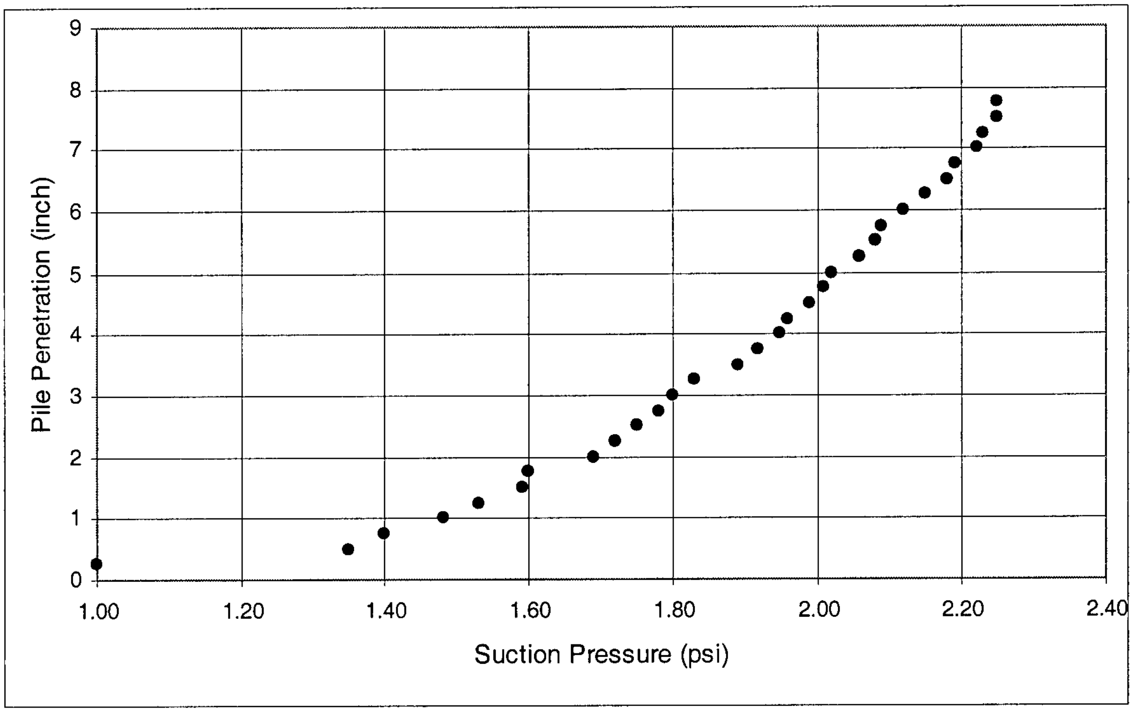


Figure I16. Suction Pressure vs. Pile Penetration (Series 4 - D)

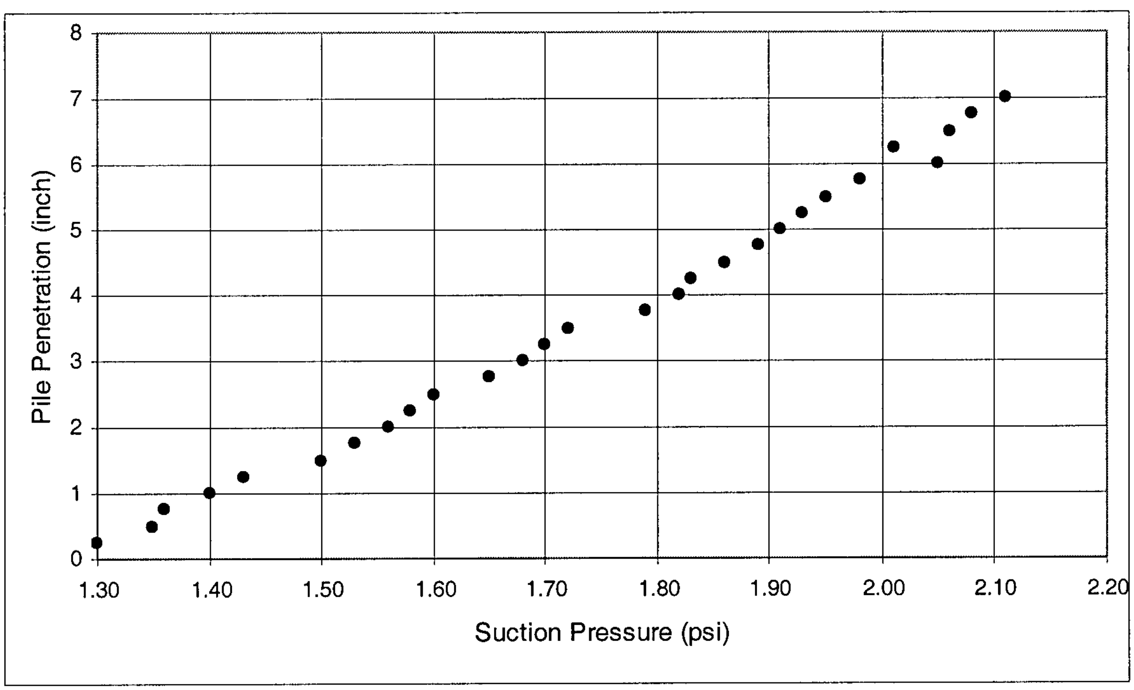


Figure I17. Suction Pressure vs. Pile Penetration (Series 4 - E)

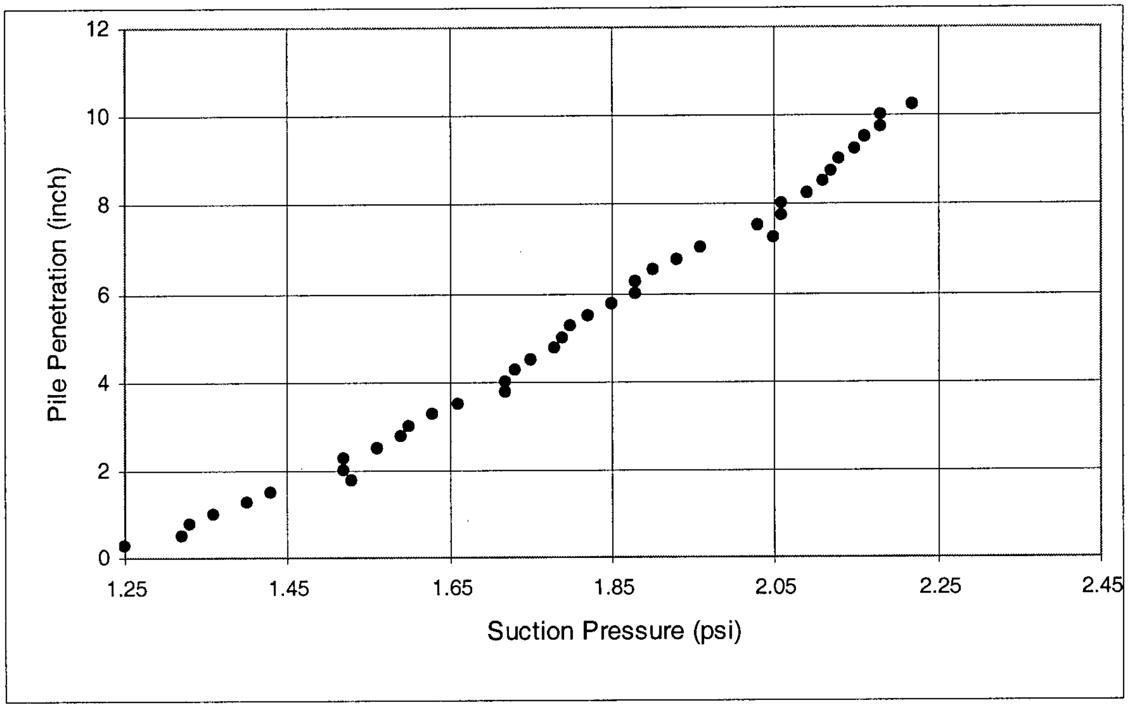


Figure I18. Suction Pressure vs. Pile Penetration (Series 5 - B)

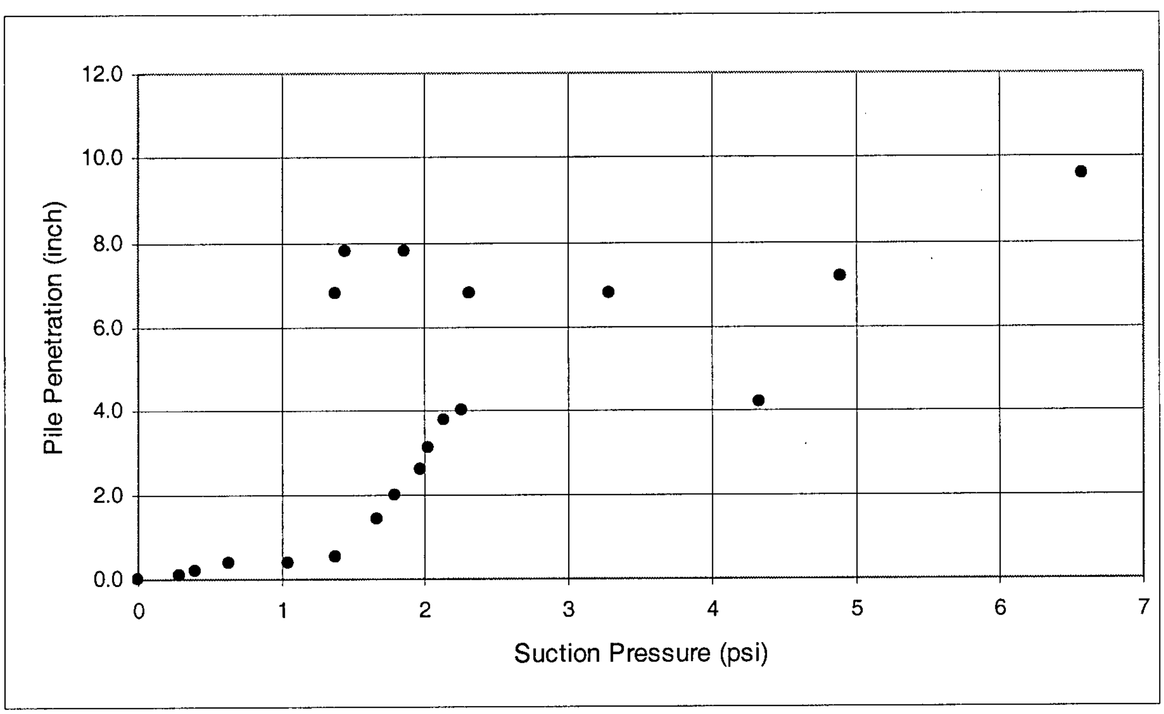


Figure I19. Suction Pressure vs. Pile Penetration (Series 5 - C)

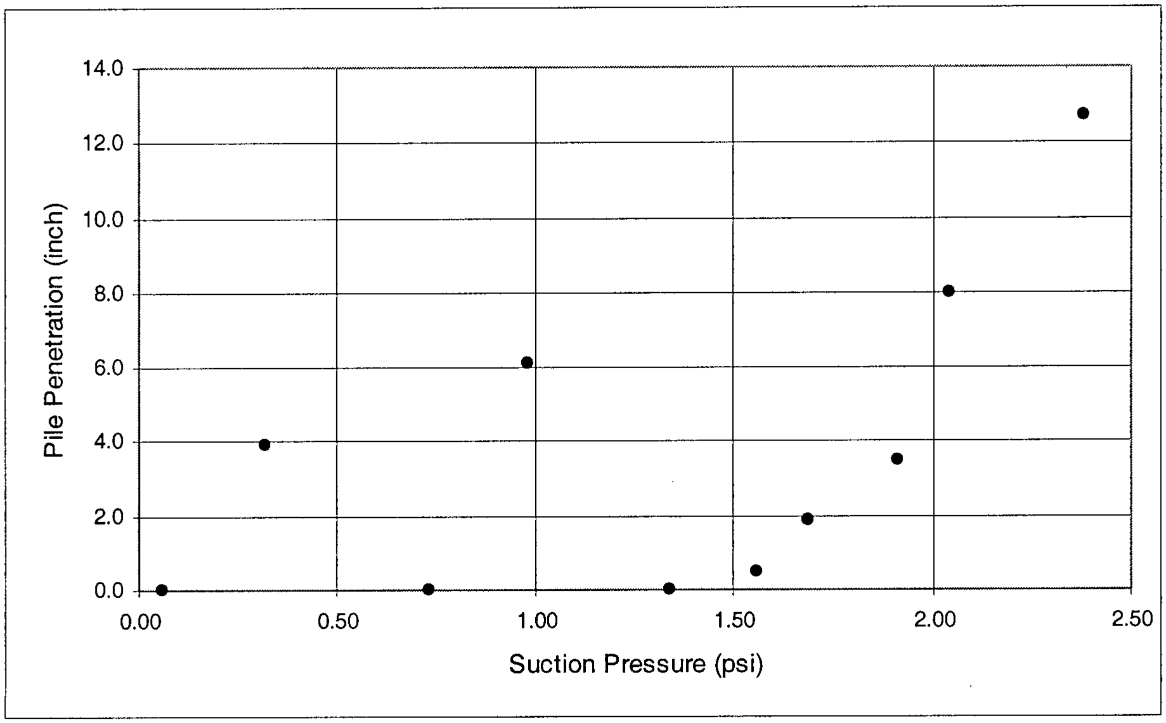


Figure I20. Suction Pressure vs. Pile Penetration (Series 5 - D)

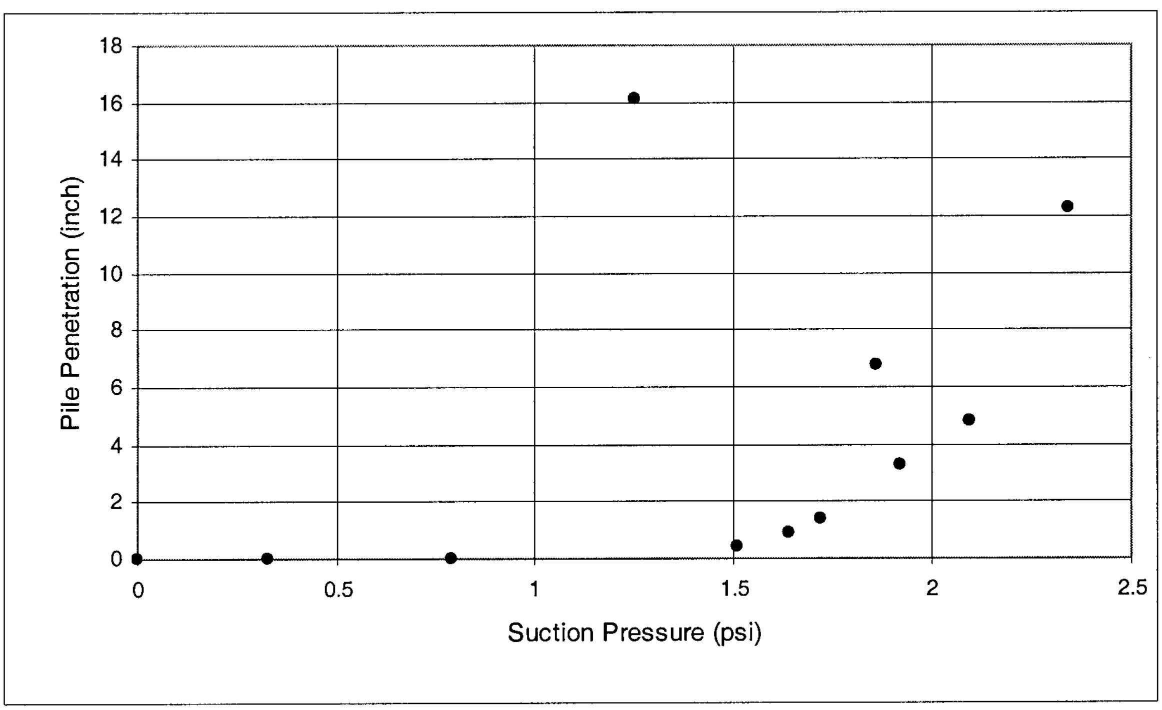


Figure I21. Suction Pressure vs. Pile Penetration (Series 6 - A)

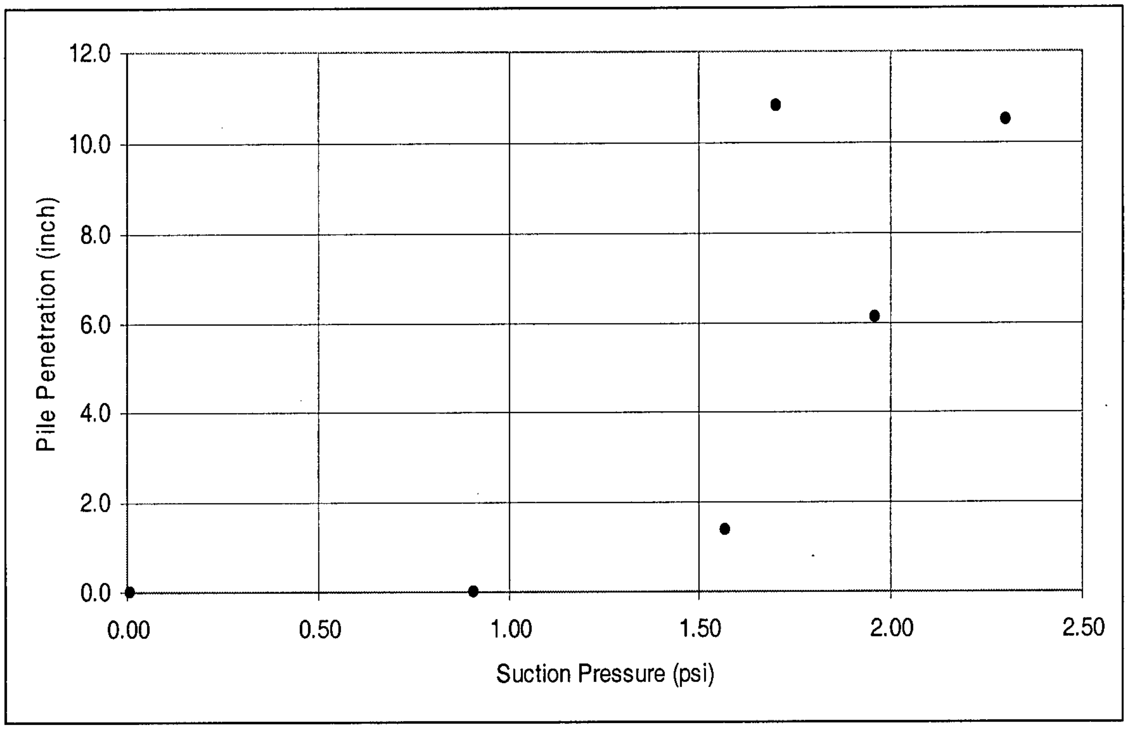


Figure I22. Suction Pressure vs. Pile Penetration (Series 6 - B)

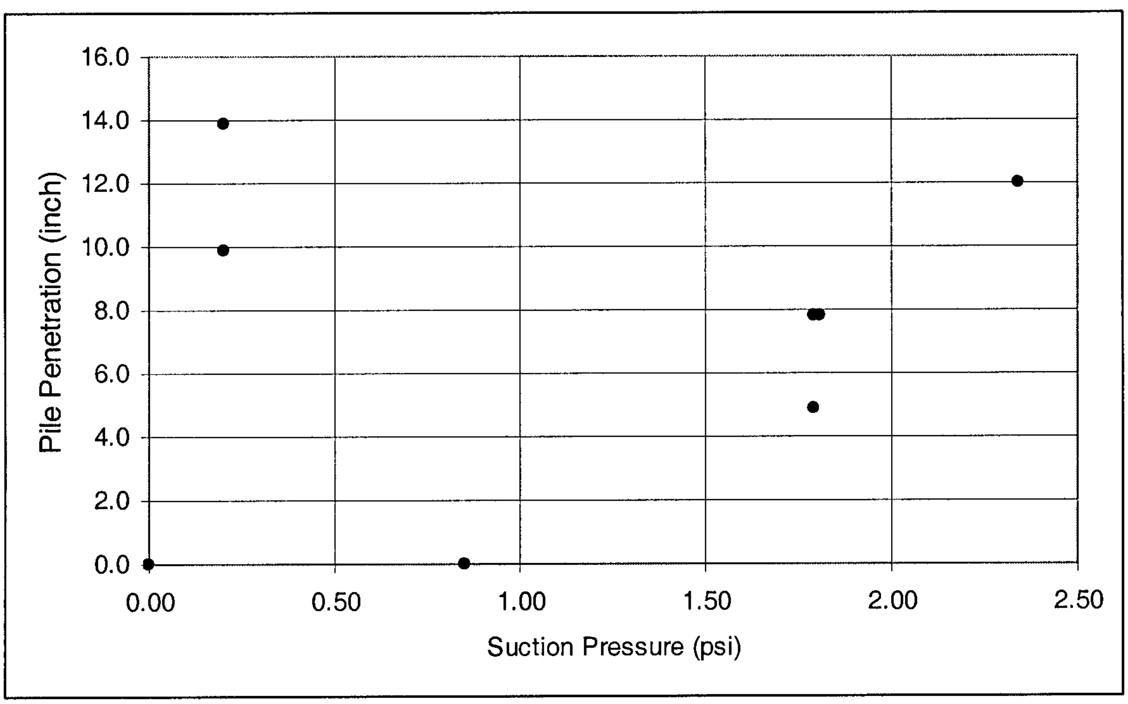


Figure I23. Suction Pressure vs. Pile Penetration (Series 6 - C)

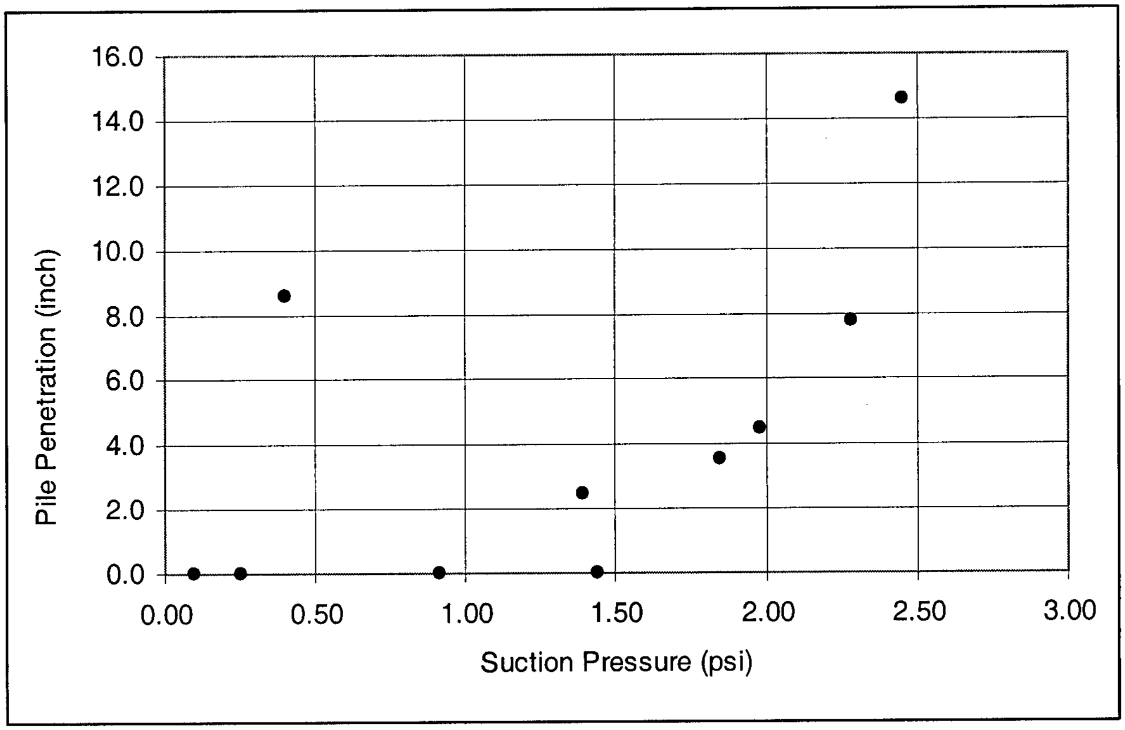


Figure I24. Suction Pressure vs. Pile Penetration (Series 6 - D)

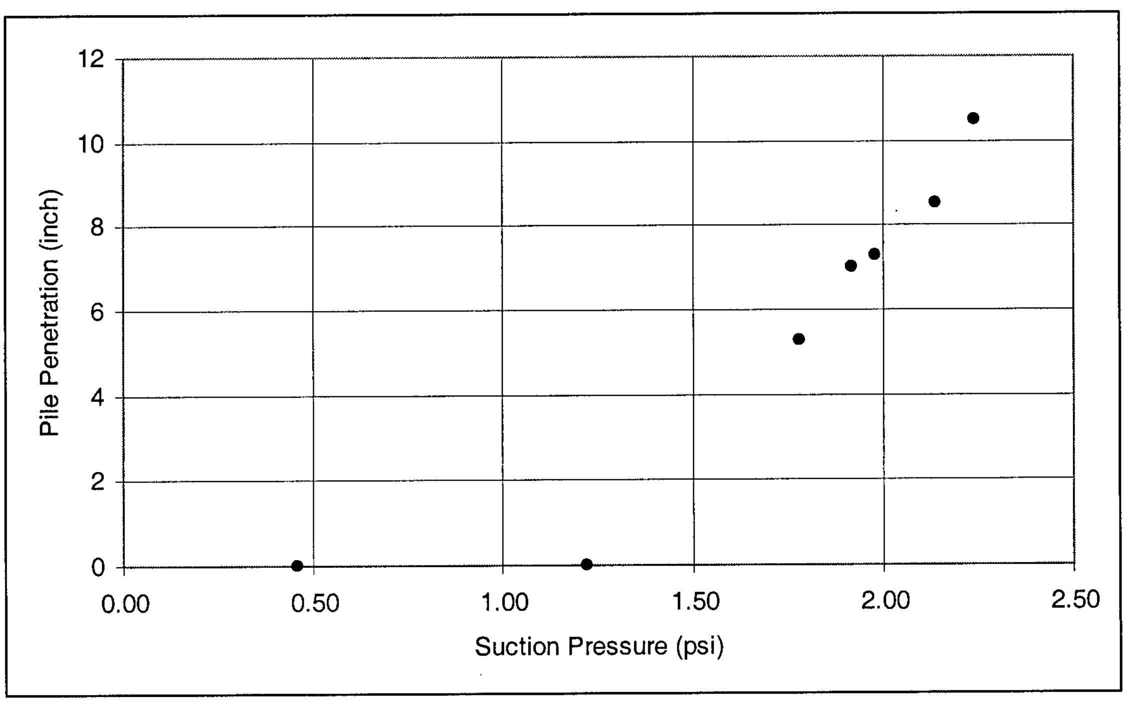


Figure I25. Suction Pressure vs. Pile Penetration (Series 7 - A)

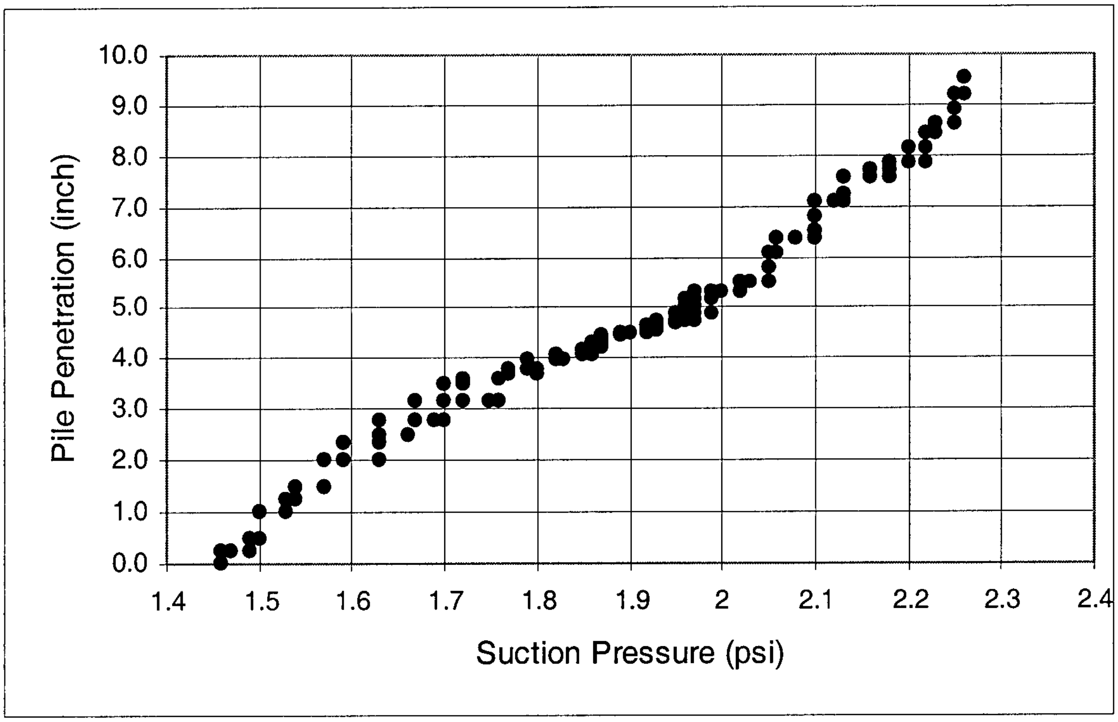


Figure I26. Suction Pressure vs. Pile Penetration (Series 7 - B)

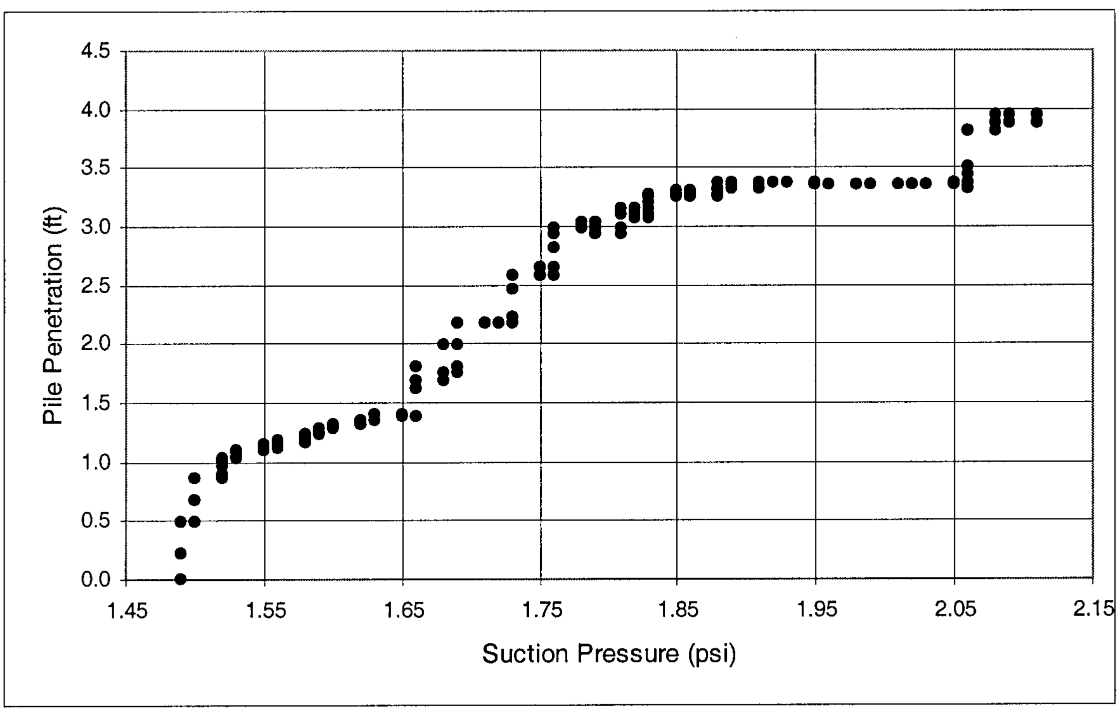


Figure I27. Suction Pressure vs. Pile Penetration (Series 7 - C)

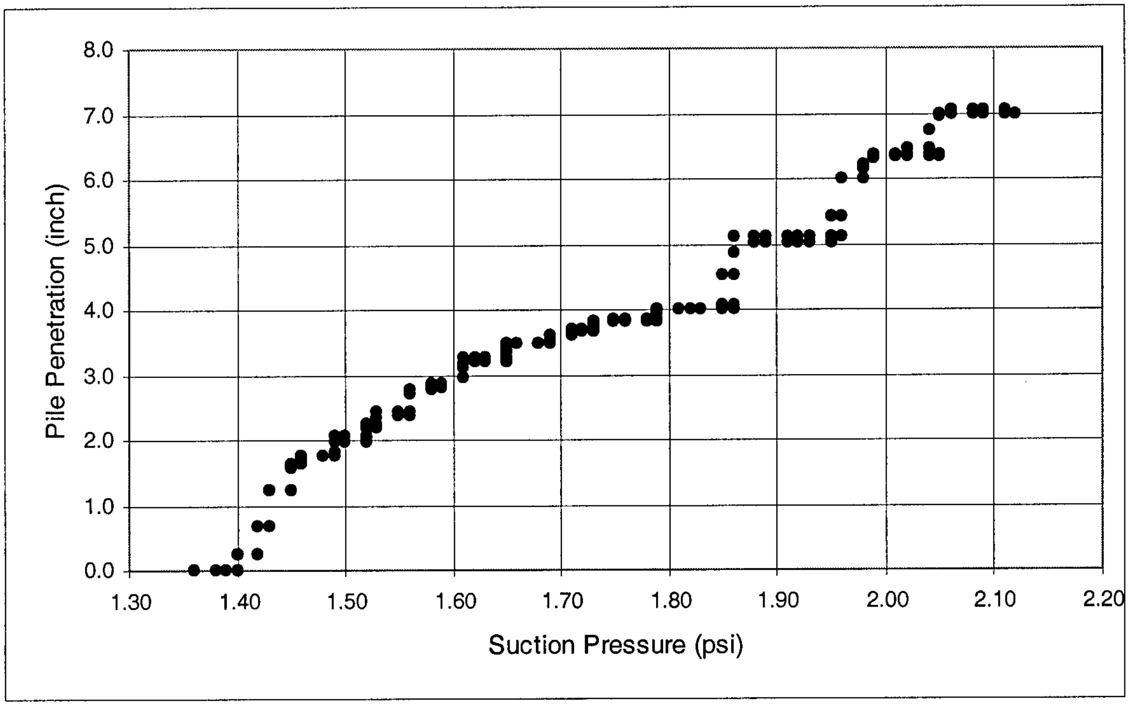


Figure I28. Suction Pressure vs. Pile Penetration (Series 7 - D)

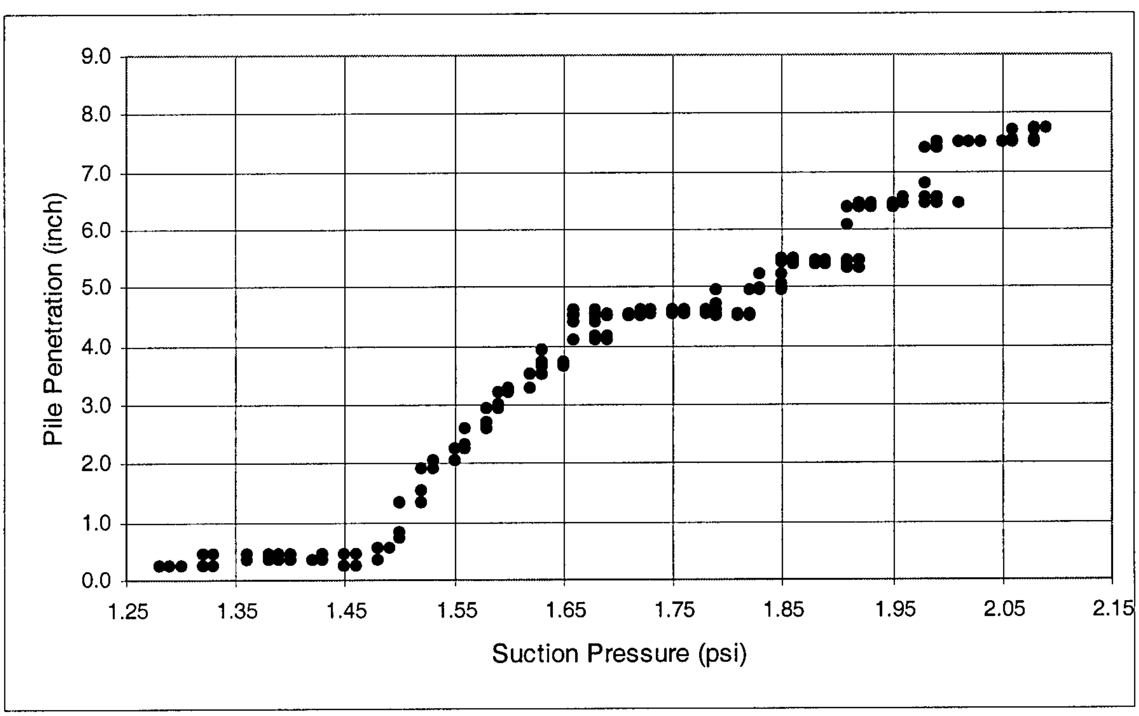


Figure I29. Suction Pressure vs. Pile Penetration (Series 8 - B)

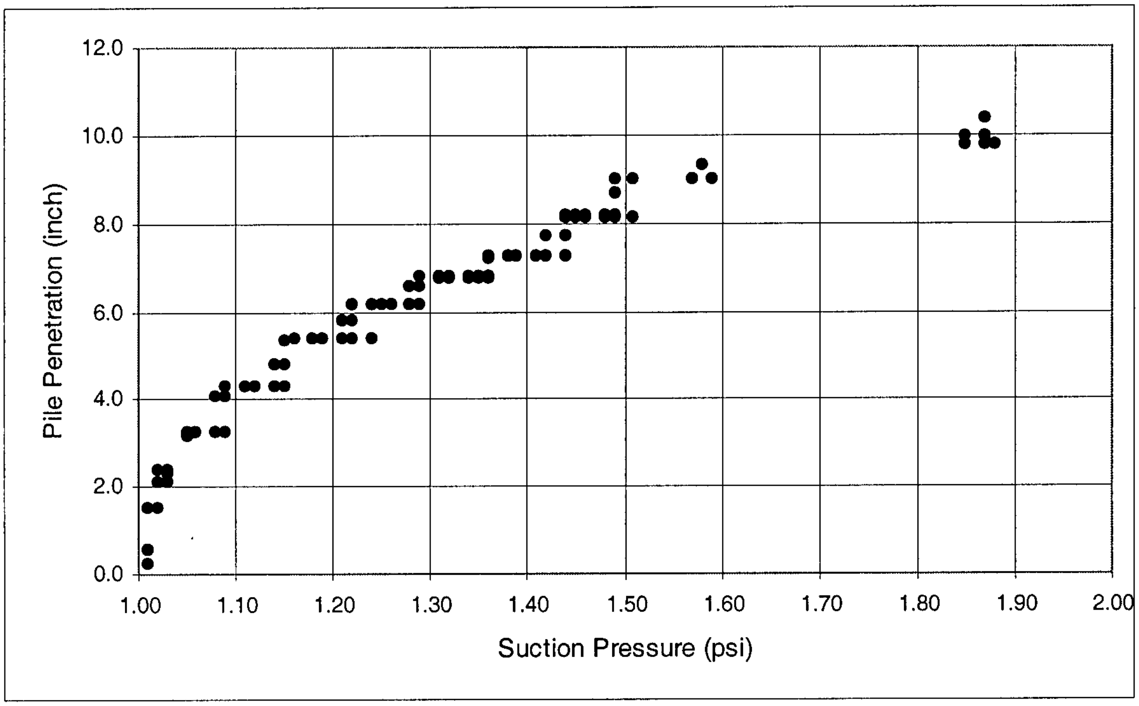


Figure I30. Suction Pressure vs. Pile Penetration (Series 8 - C)

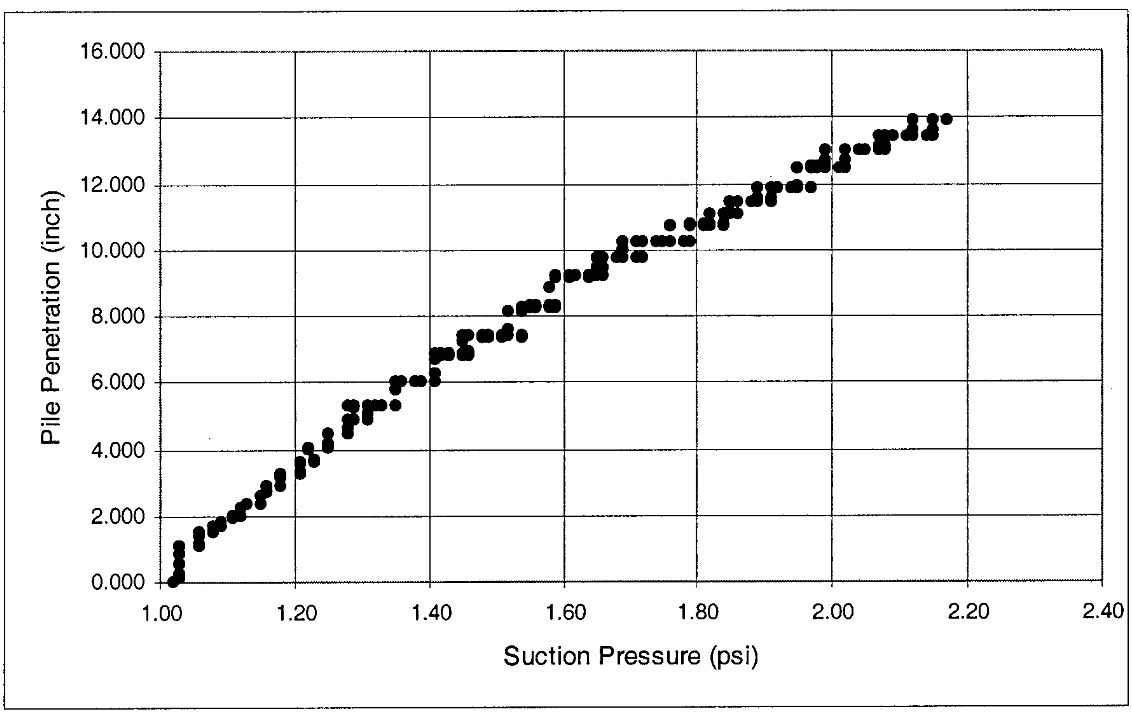


Figure I31. Suction Pressure vs. Pile Penetration (Series 9 - A)

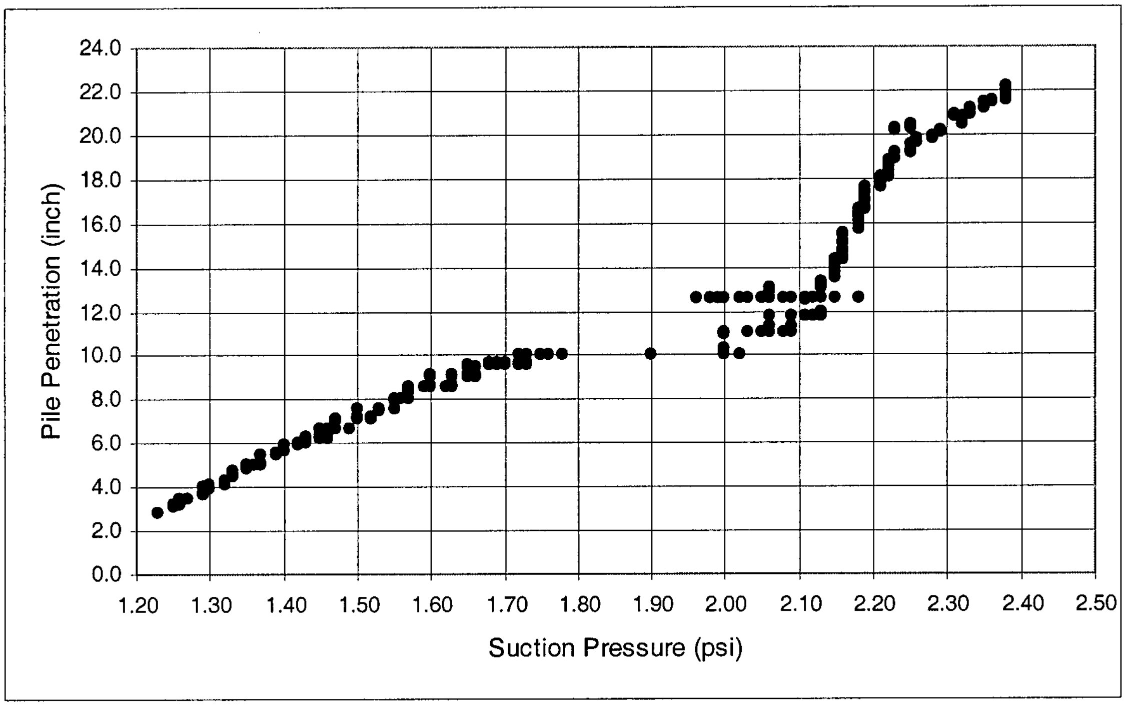


Figure I32. Suction Pressure vs. Pile Penetration (Series 9 - C)

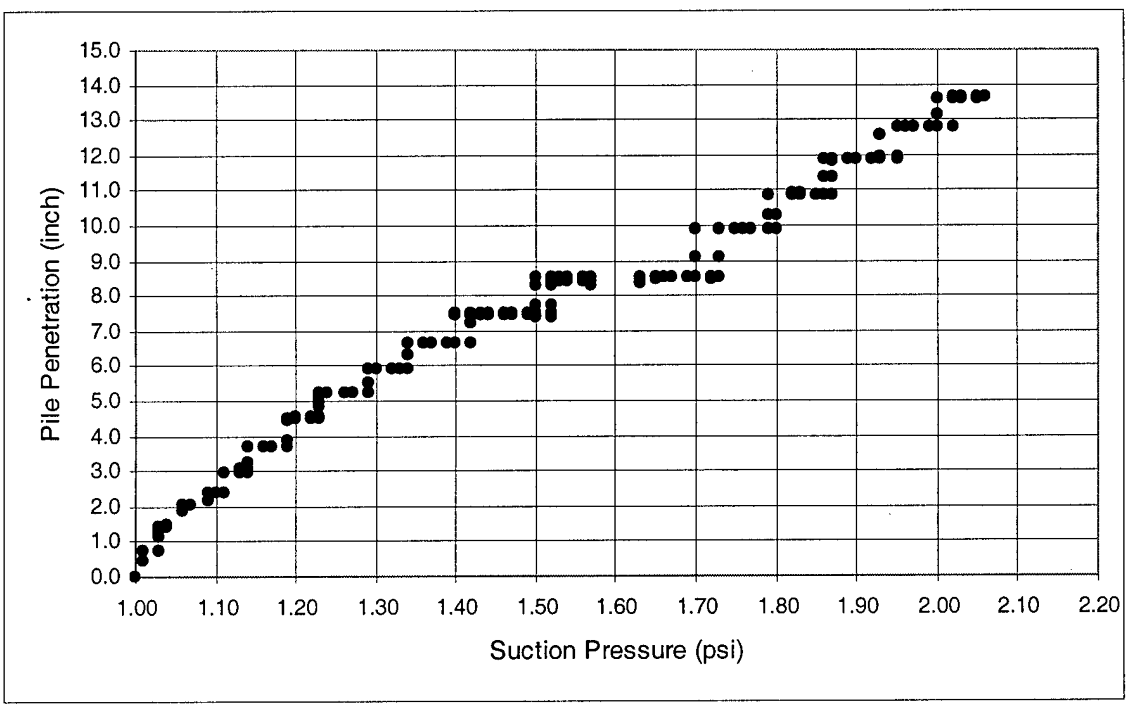


Figure I33. Suction Pressure vs. Pile Penetration (Series 9 - D)

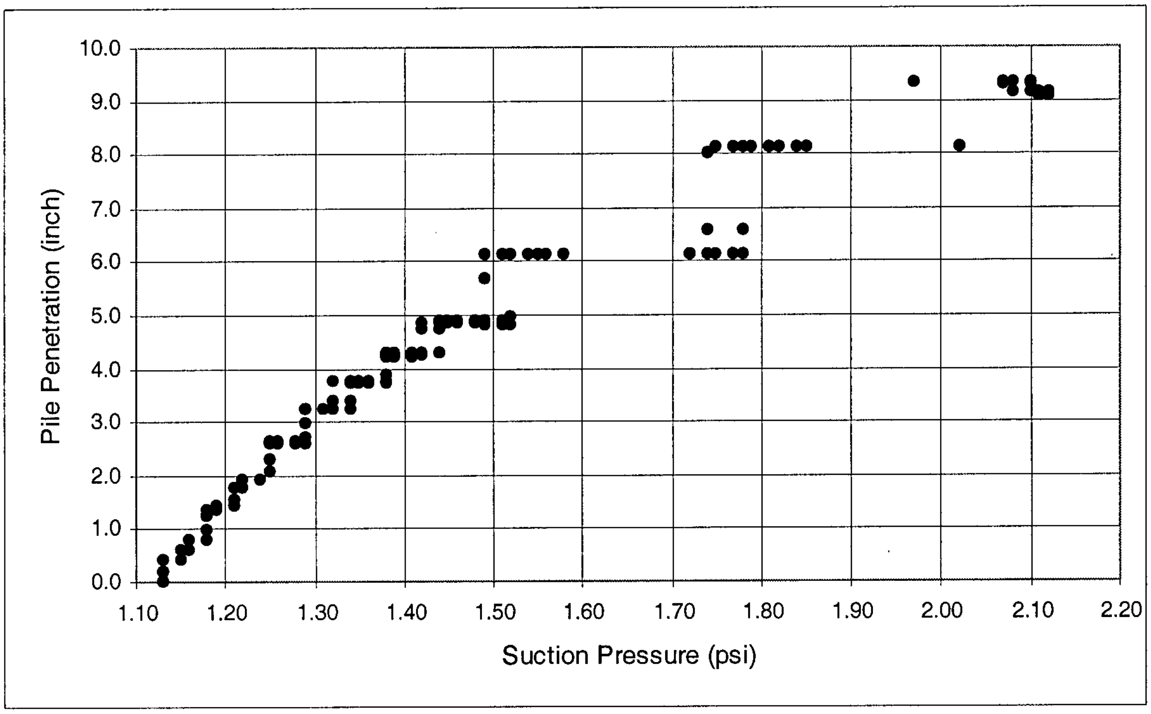


Figure I34. Suction Pressure vs. Pile Penetration (Series 10 - A)

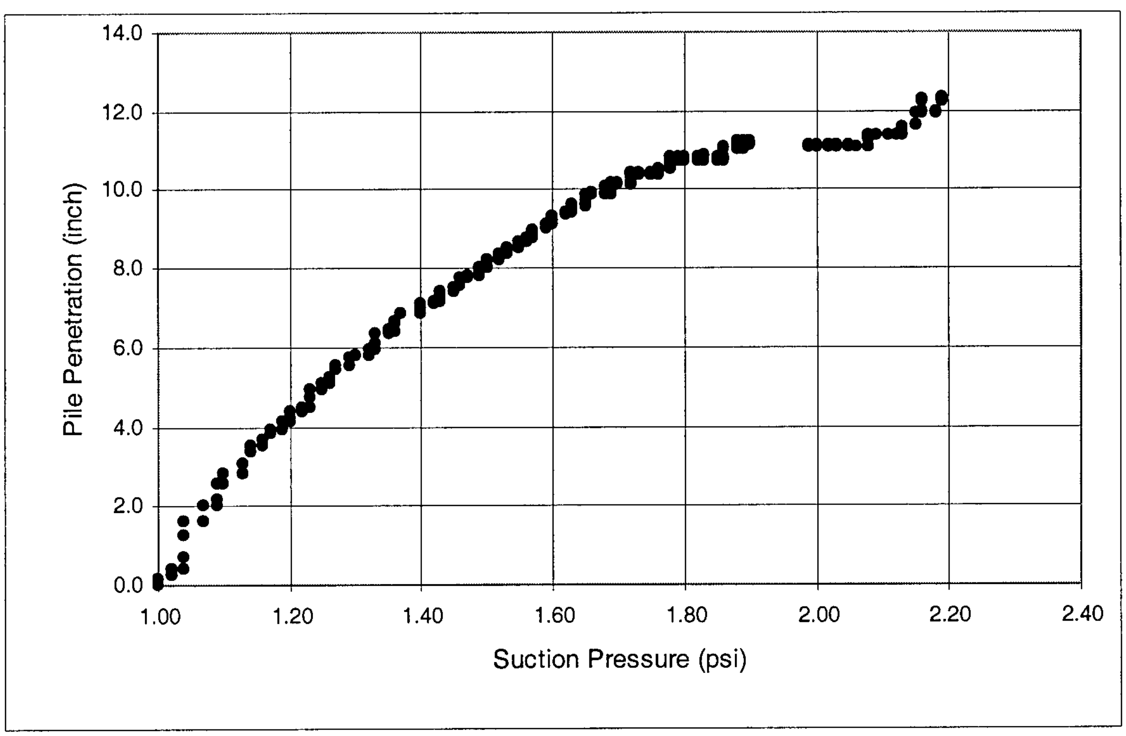


Figure I35. Suction Pressure vs. Pile Penetration (Series 10 - B)

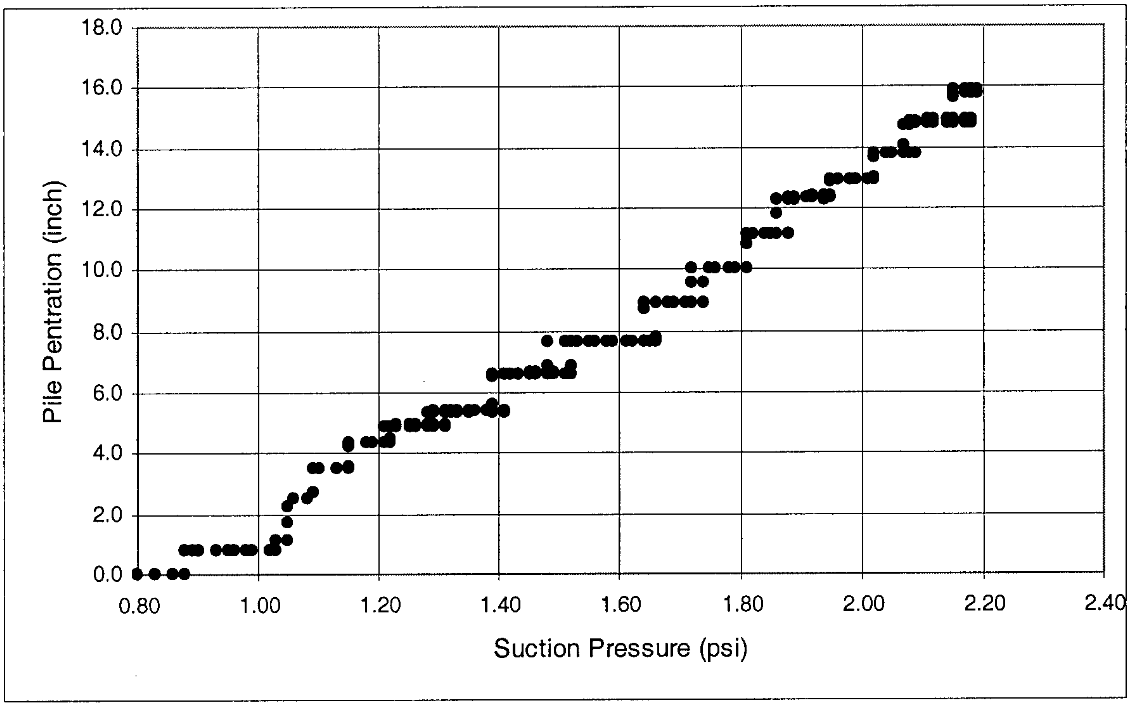


Figure I36. Suction Pressure vs. Pile Penetration (Series 10 - E)

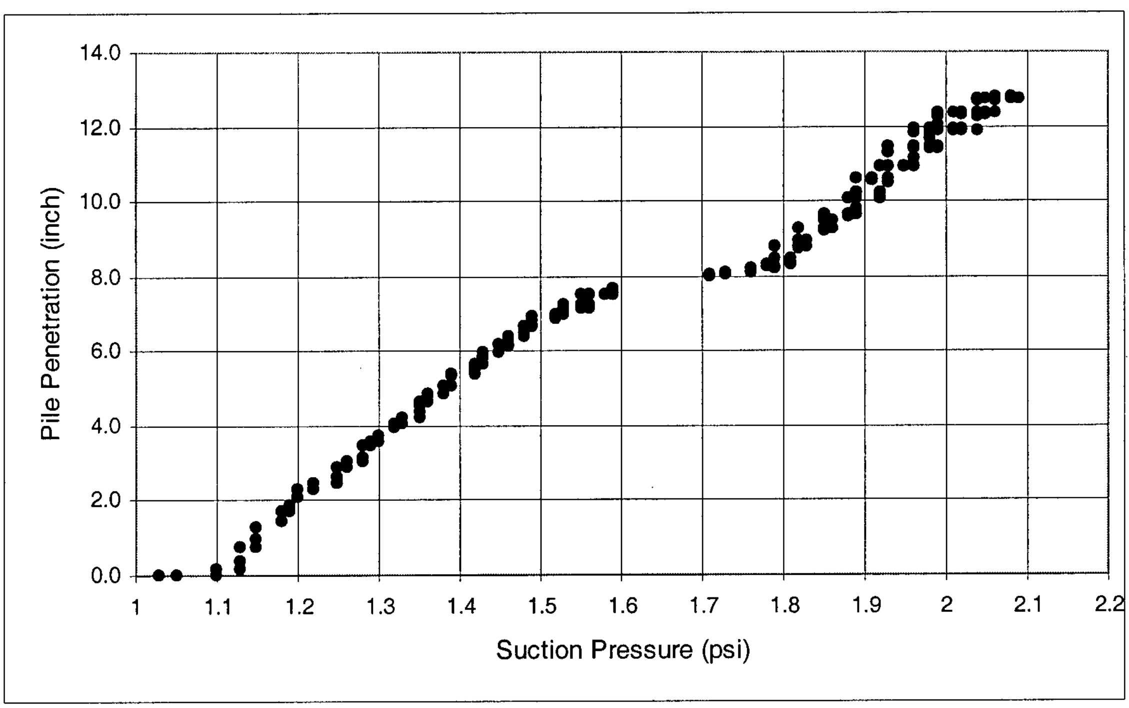


Figure I37. Suction Pressure vs. Pile Penetration (Series 11 - A)

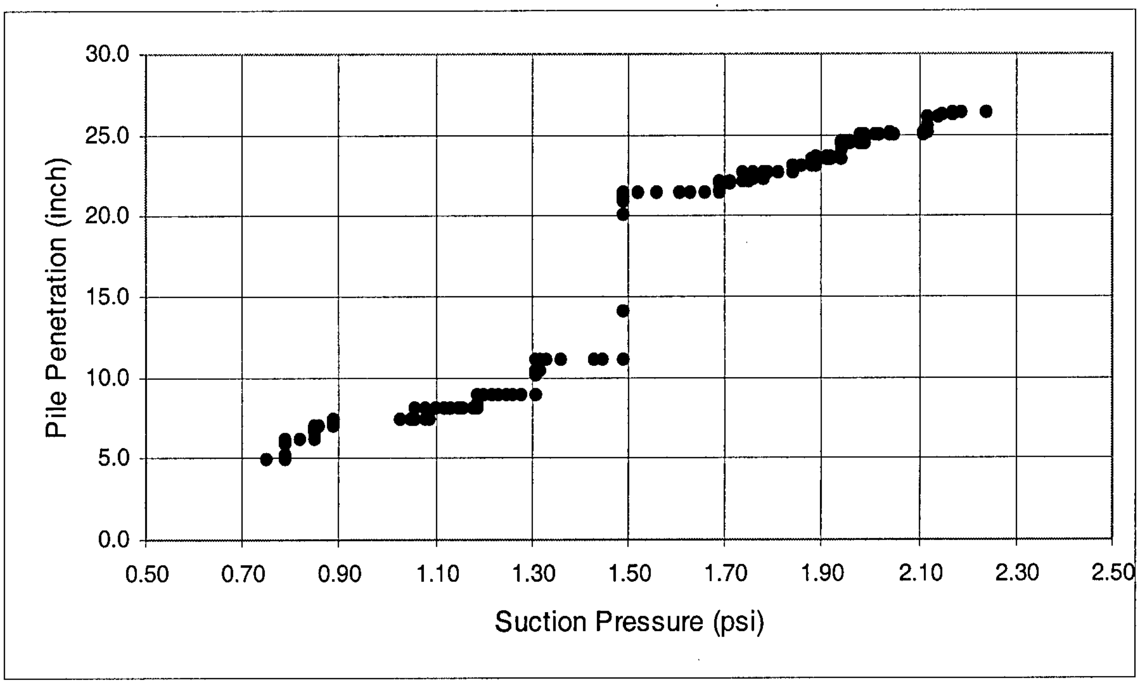


Figure I38. Suction Pressure vs. Pile Penetration (Series 11 - B)

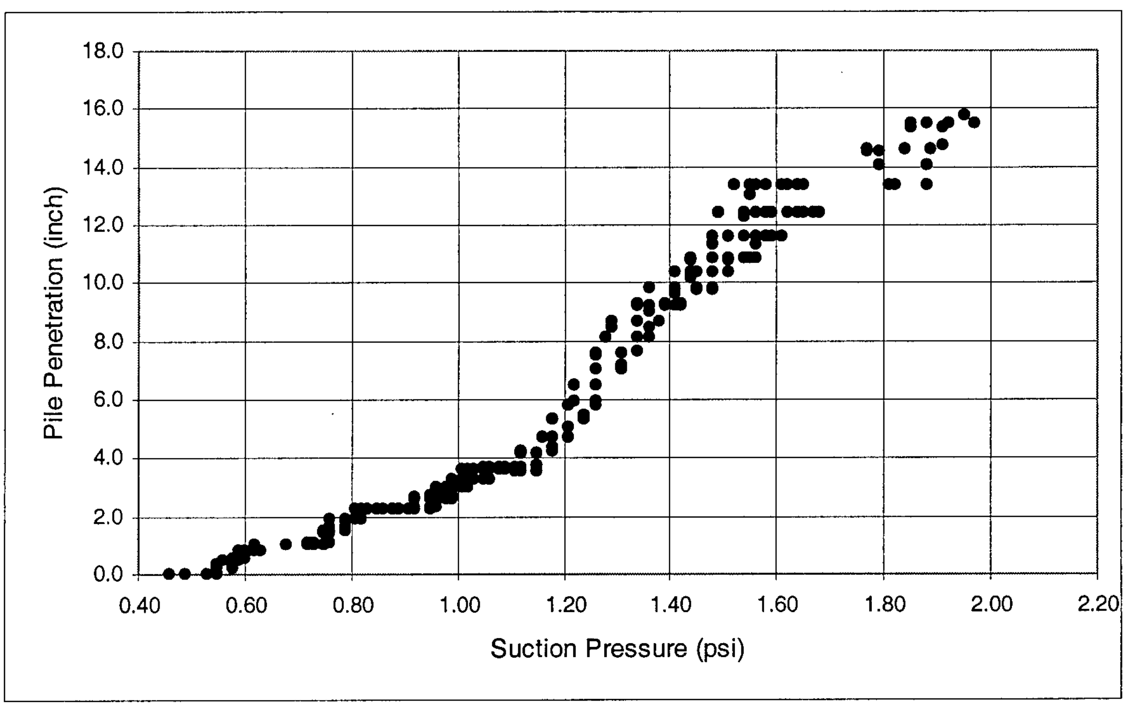


Figure I39. Suction Pressure vs. Pile Penetration (Series 11 - D)

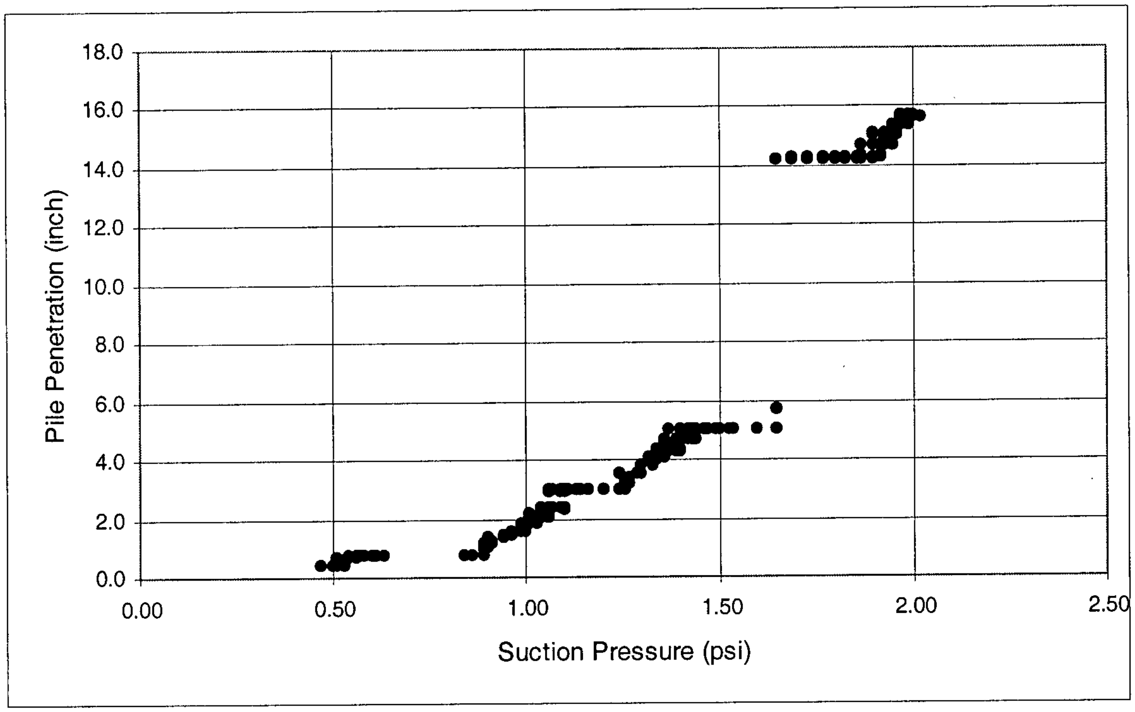


Figure I40. Suction Pressure vs. Pile Penetration (Series 12 - B)

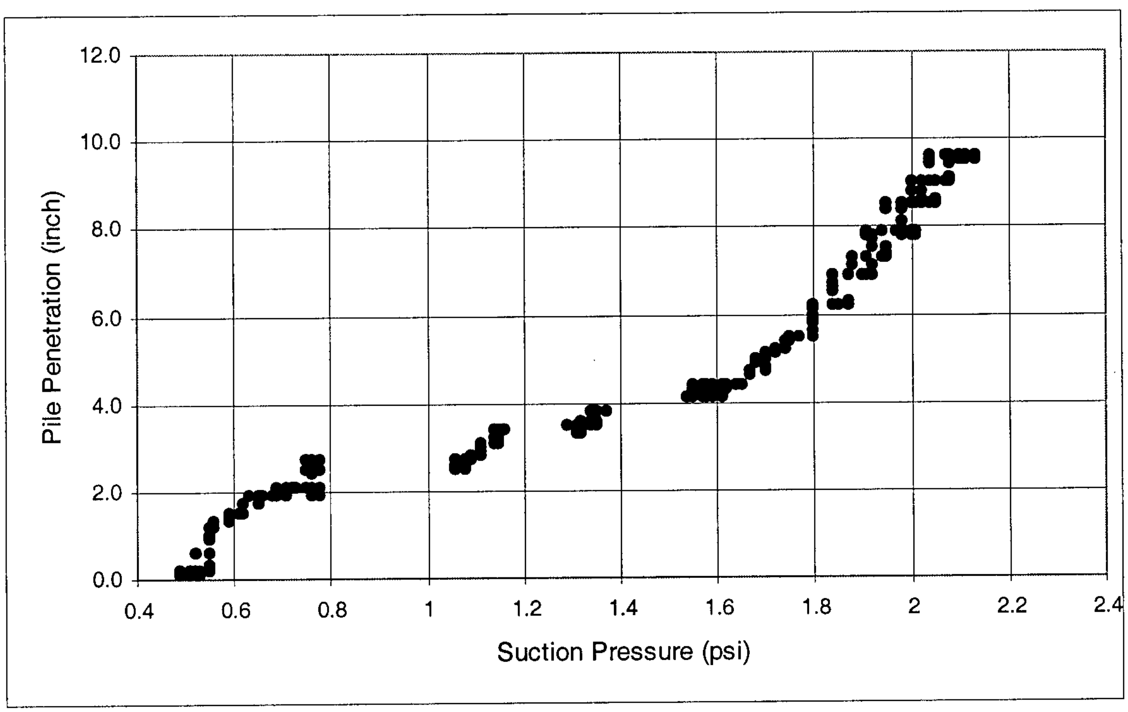


Figure I41. Suction Pressure vs. Pile Penetration (Series 12 - C)

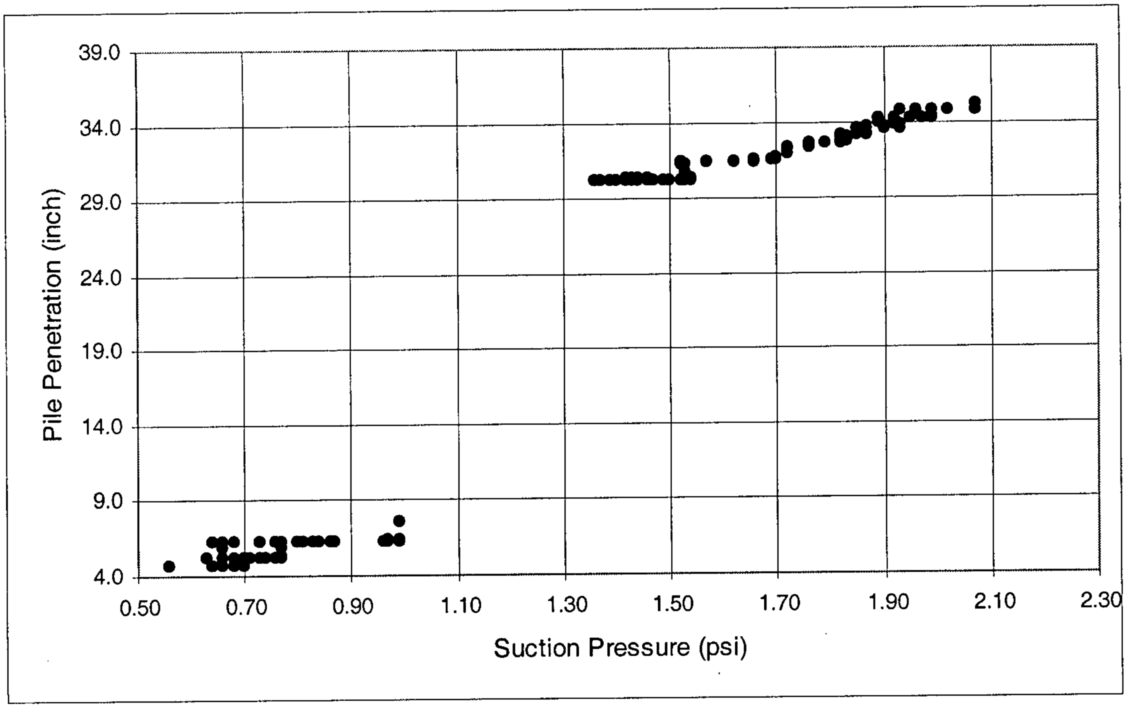


Figure I42. Suction Pressure vs. Pile Penetration (Series 12 - D)

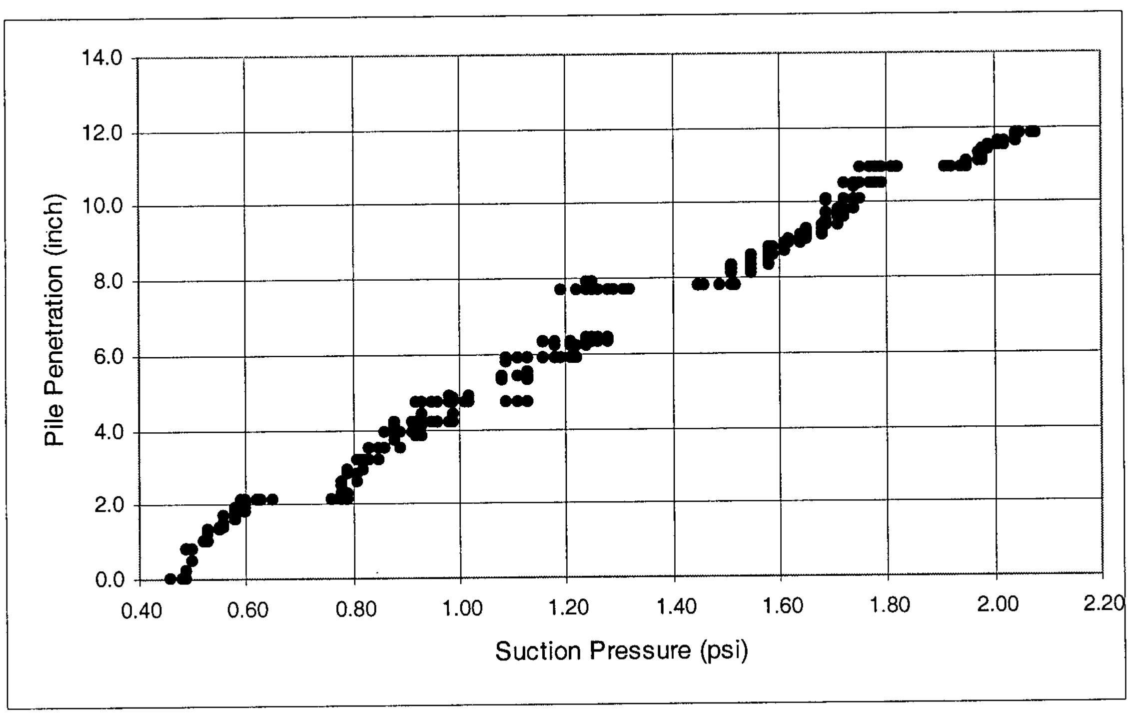


Figure I43. Suction Pressure vs. Pile Penetration (Series 14 - A)

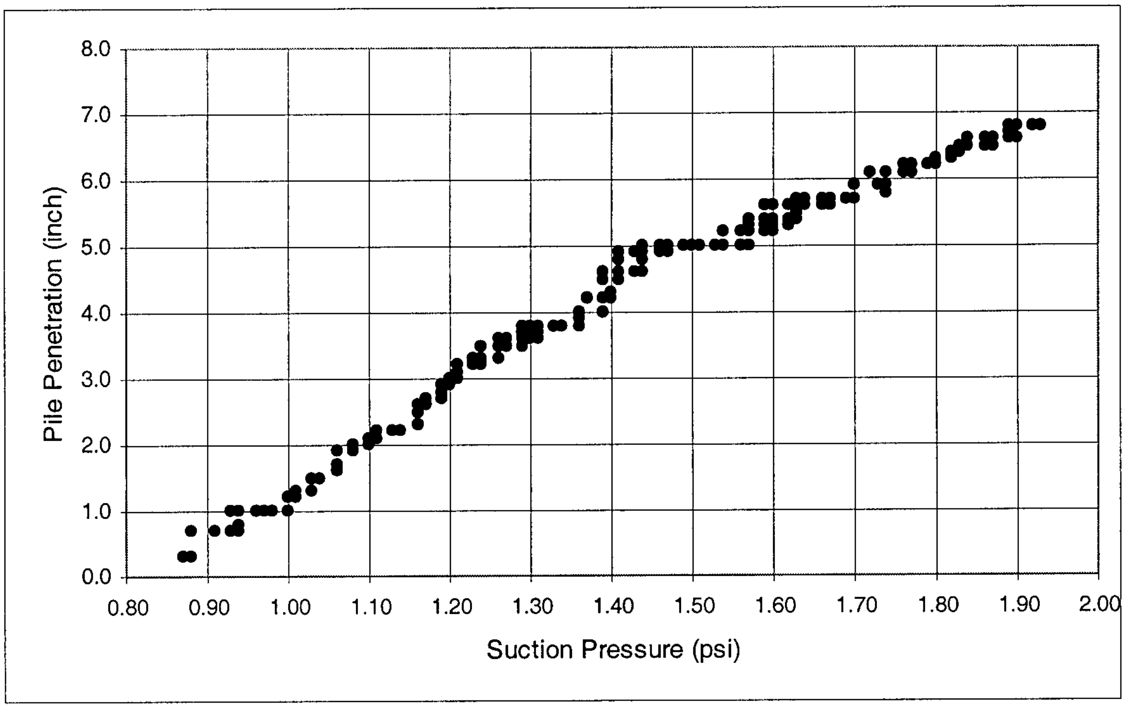


Figure I44. Suction Pressure vs. Pile Penetration (Series 14 - B)

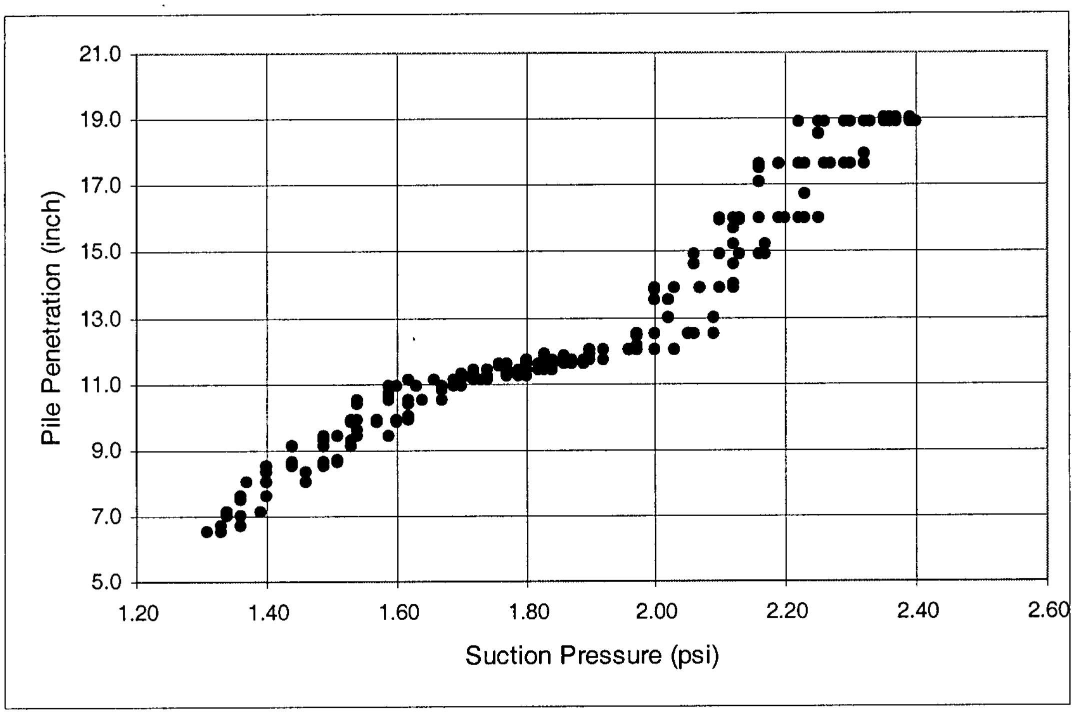


Figure I45. Suction Pressure vs. Pile Penetration (Series 15 - A)

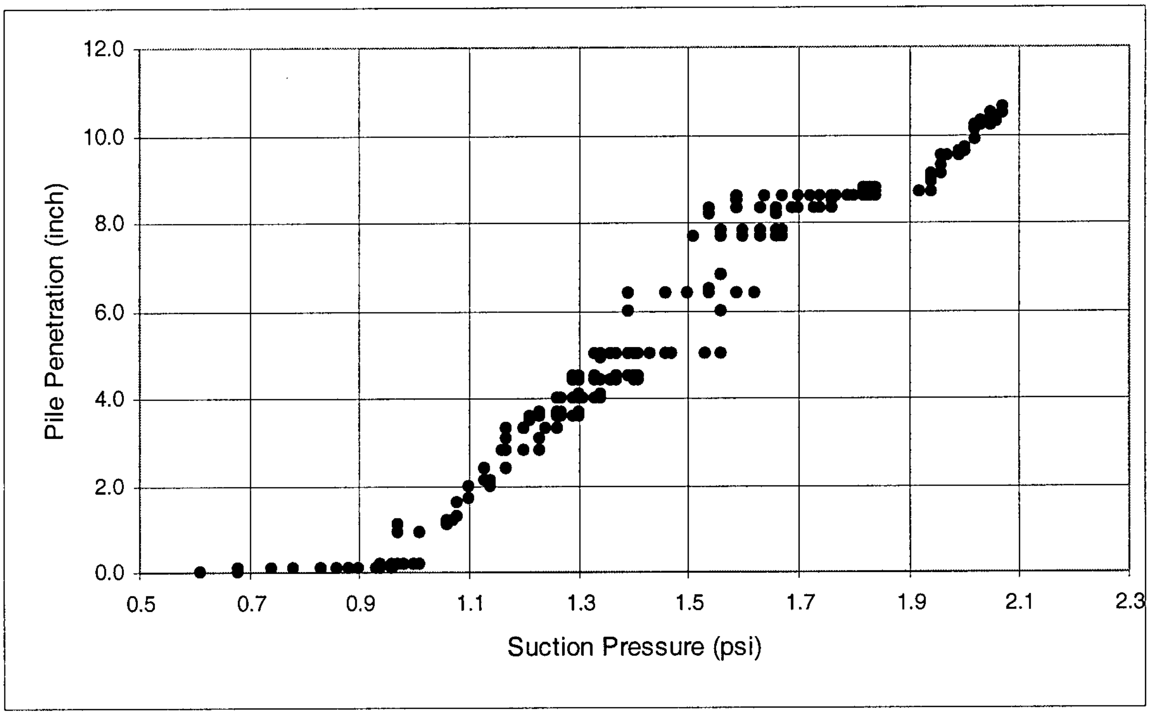


Figure I46. Suction Pressure vs. Pile Penetration (Series 15 - C)

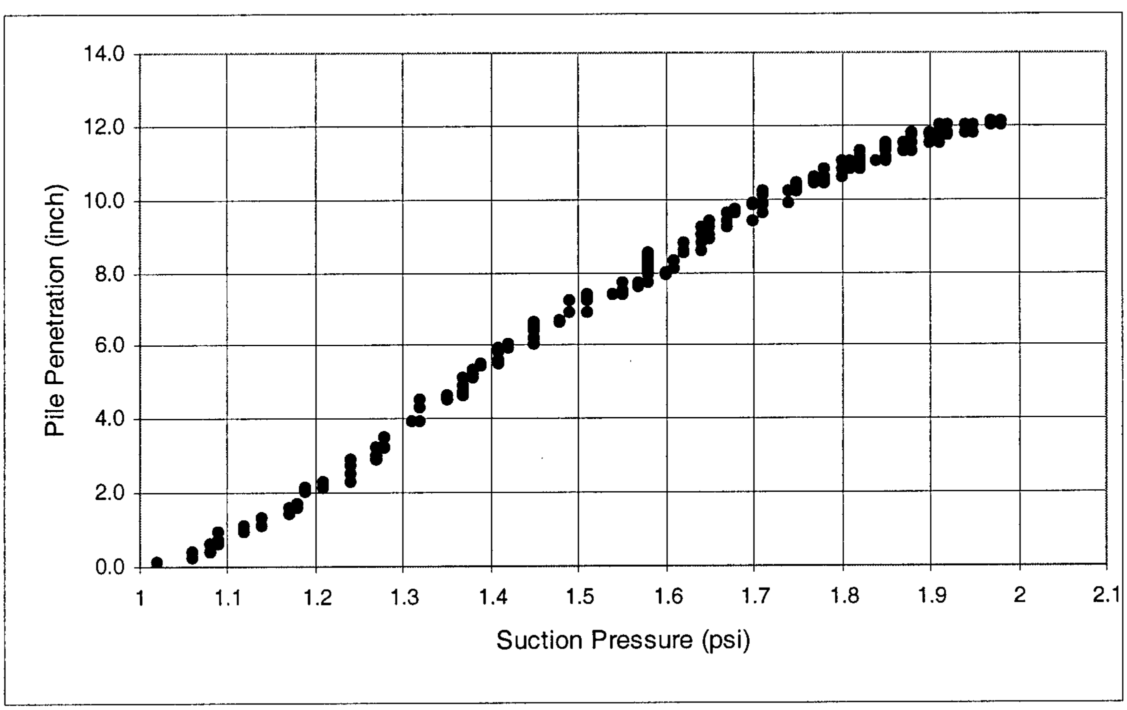


Figure I47. Suction Pressure vs. Pile Penetration (Series 15 - D)

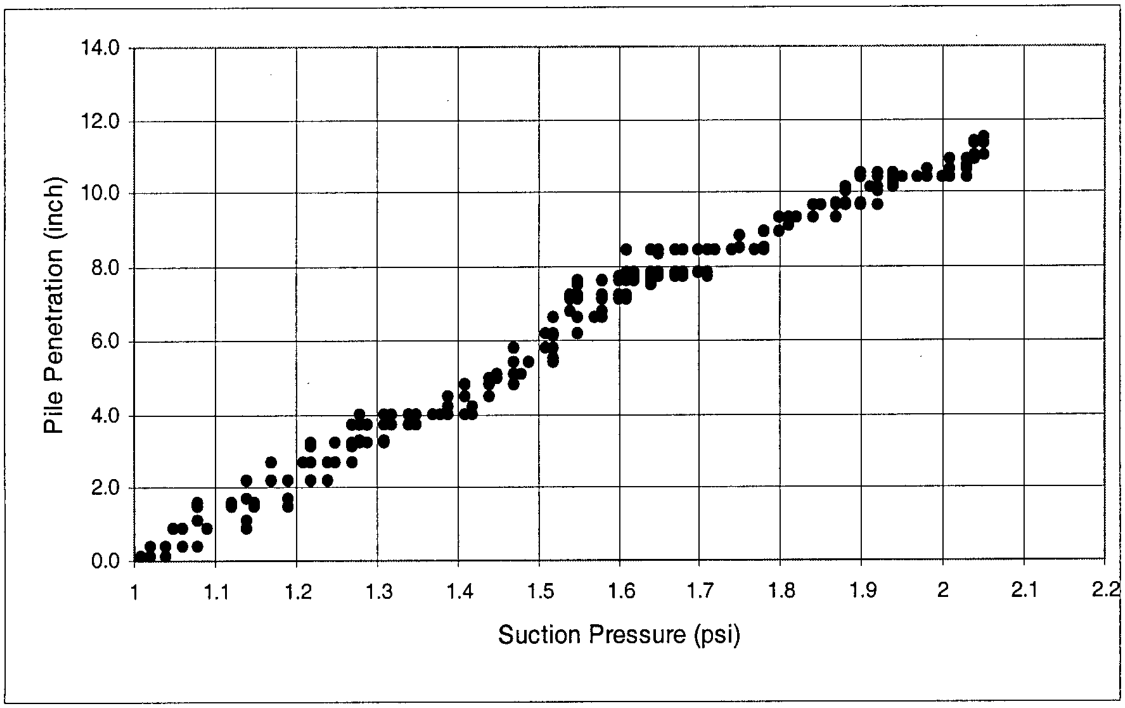


Figure I48. Suction Pressure vs. Pile Penetration (Series 17 - A)

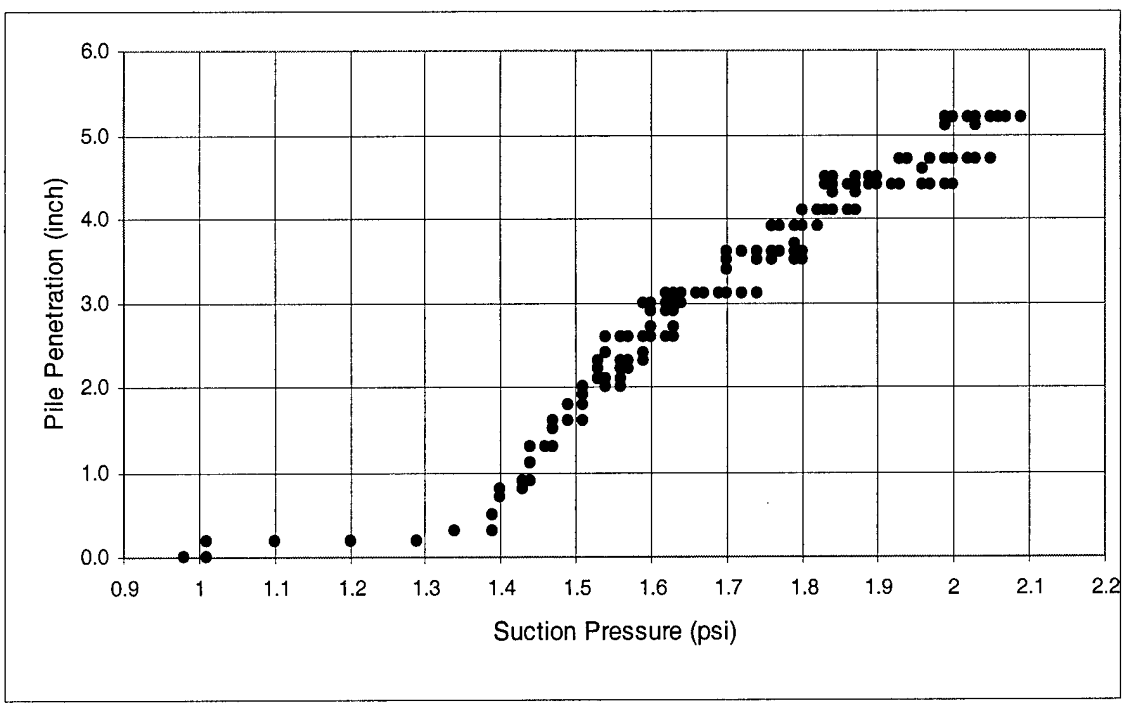


Figure I49. Suction Pressure vs. Pile Penetration (Series 17 - B)

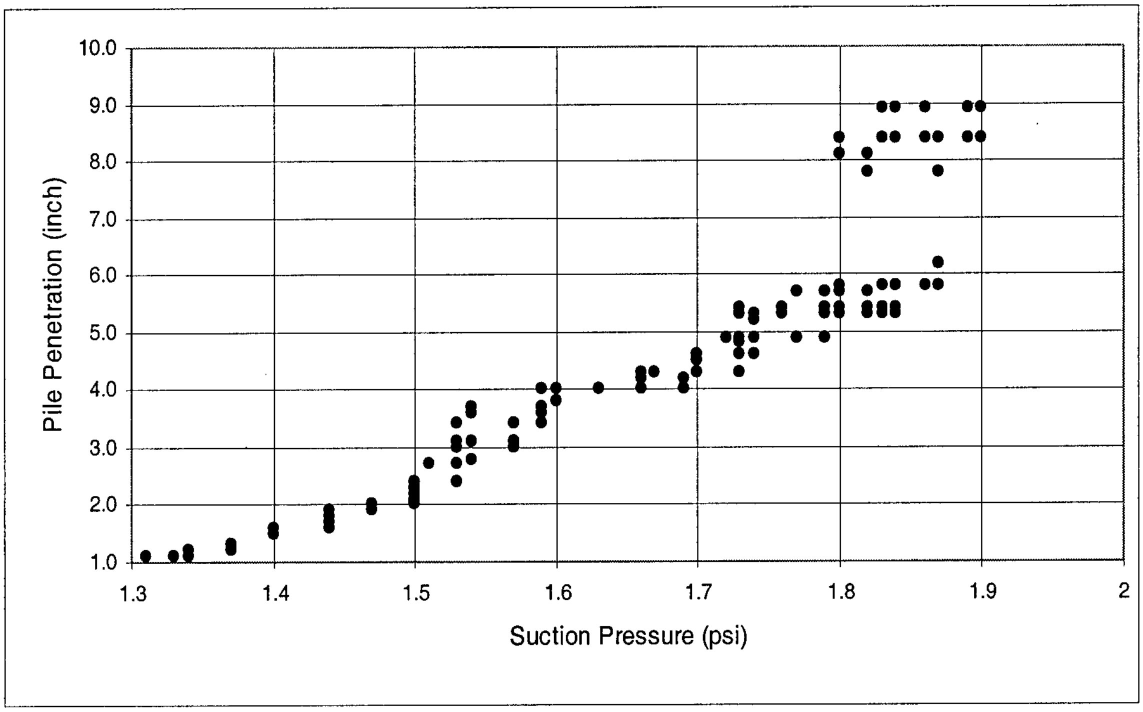


Figure I50. Suction Pressure vs. Pile Penetration (Series 18 - A)

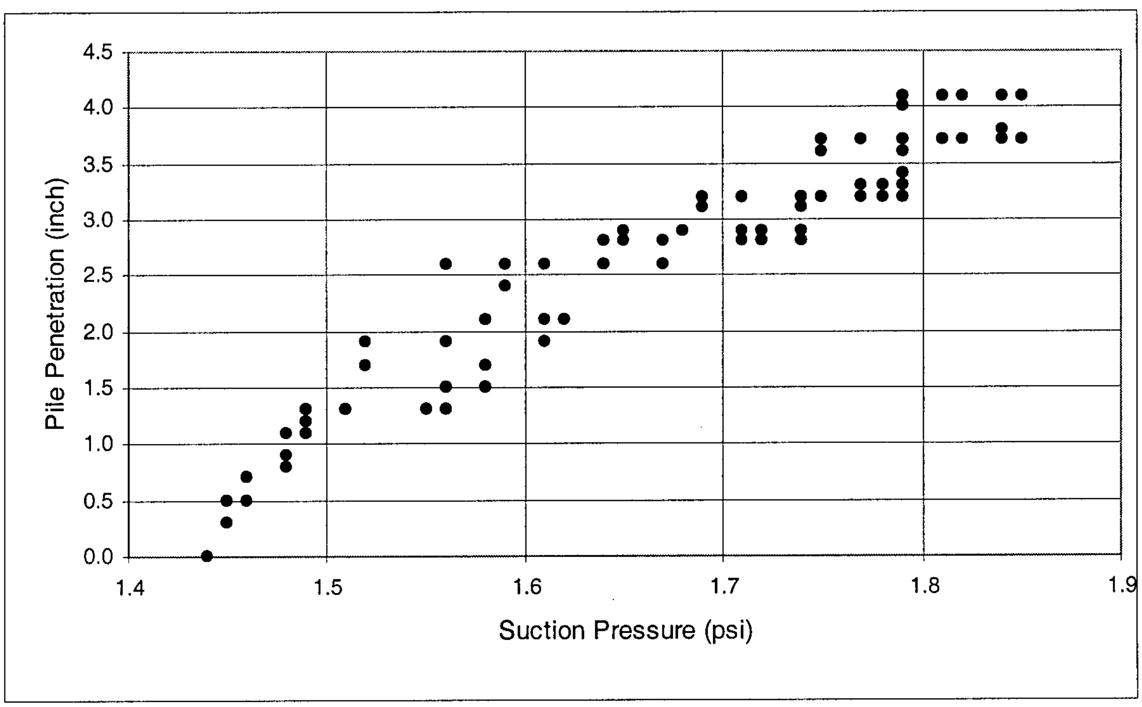


Figure I51. Suction Pressure vs. Pile Penetration (Series 18 - B)

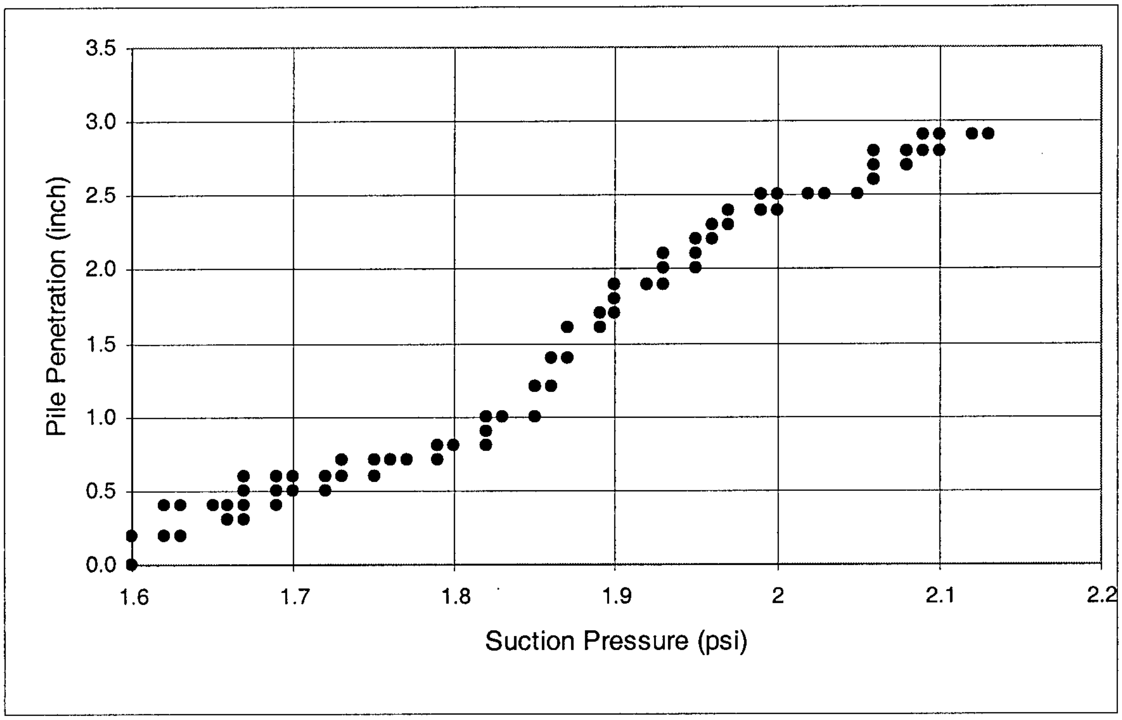


Figure I52. Suction Pressure vs. Pile Penetration (Series 18 - C)

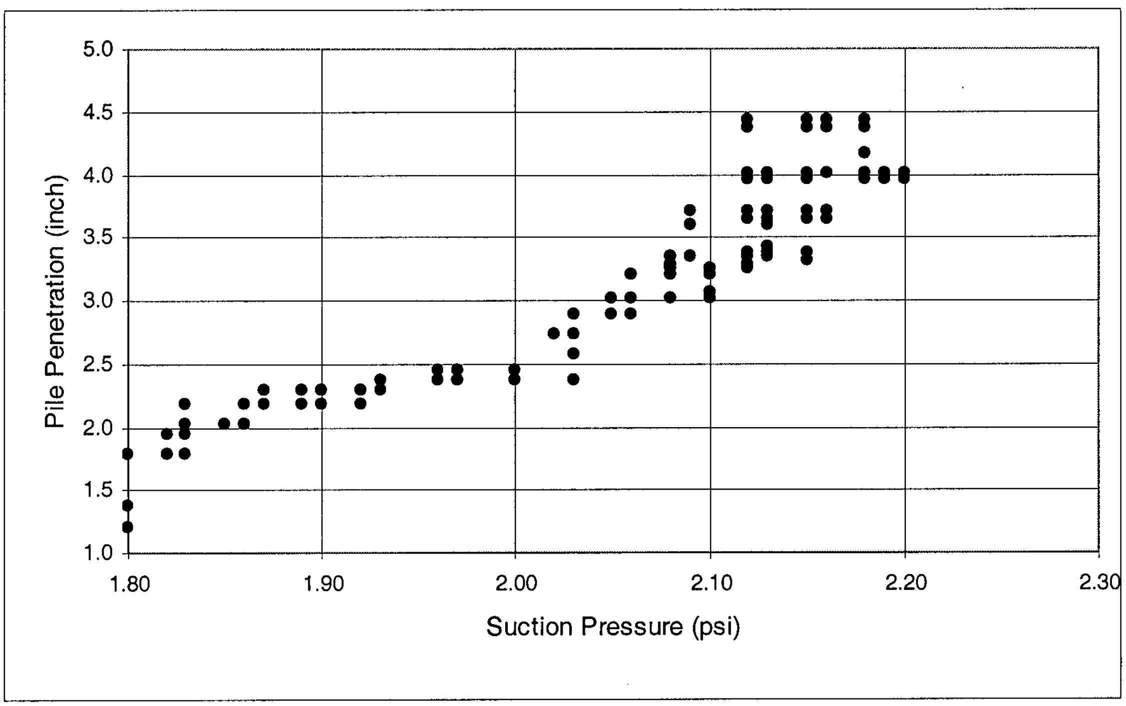
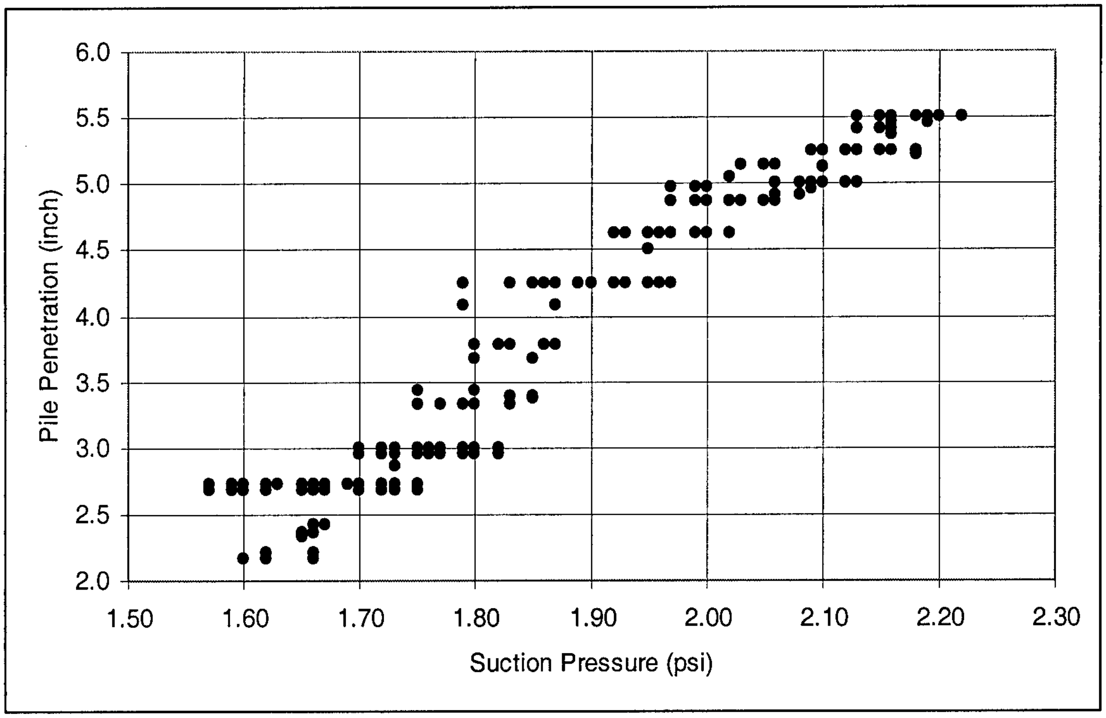


Figure I53. Suction Pressure vs. Pile Penetration (Series 18 - E)



APPENDIX – 3. CALIBRATION OF MOBILIZED EFFECTIVE SOIL FRICTION ANGLE RATIO (α)

TABLE OF TABLES

Table A1	Analysis Results (Series 1-B ~ 1-D)
Table A2	Analysis Results (Series 1-E ~ 2-A)
Table A3	Analysis Results (Series 2-B ~ 2-C)
Table A4	Analysis Results (Series 2-D ~ 2-E)
Table A5	Analysis Results (Series 2-F ~ 3-A)
Table A6	Analysis Results (Series 3-B ~ 3-C)
Table A7	Analysis Results (Series 3-D ~ 4-B)
Table A8	Analysis Results (Series 4-C ~ 4-E)
Table A9	Analysis Results (Series 5-B ~ 6-B)
Table A10	Analysis Results (Series 6-C ~ 7-B)
Table A11	Analysis Results (Series 7-C ~ 8-B)
Table A12	Analysis Results (Series 8-C ~ 9-A)
Table A13	Analysis Results (Series 9-C ~ 9-D)
Table A14	Analysis Results (Series 10-A ~ 10-E)
Table A15	Analysis Results (Series 11-A ~ 11-D)
Table A16	Analysis Results (Series 12-B ~ 12-D)
Table A17	Analysis Results (Series 14-A ~ 15-A)
Table A18	Analysis Results (Series 15-C ~ 17-B)
Table A19	Analysis Results (Series 18-A ~ 18-E)

Table A1. Analysis Results (Series 1-B ~ 1-D)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-max}}}$	α
1-B	A	205.92	12.00	1.0625	1.4139	2.611	0.815
		214.56	12.00	1.1250	1.5141	2.499	0.799
		254.88	12.00	1.2292	1.9815	2.425	0.784
		263.52	12.00	1.2917	2.0816	2.336	0.773
		272.16	12.00	1.3958	2.1818	2.188	0.752
		280.80	12.00	1.4792	2.2820	2.089	0.737
		329.76	12.00	1.5208	2.8495	2.168	0.740
		338.40	12.00	1.5625	2.9497	2.133	0.734
		345.60	12.00	1.6250	3.0331	2.070	0.724
		354.24	12.00	1.7083	3.1333	1.990	0.709
1-C	A	108.00	12.00	1.0417	0.3460	2.162	0.799
		148.32	12.00	1.1250	0.7983	2.146	0.787
		190.08	12.00	1.2292	1.2667	2.100	0.771
		198.72	12.00	1.2917	1.3637	2.026	0.759
		256.32	12.00	1.4375	2.0098	1.981	0.740
		263.52	12.00	1.5000	2.0906	1.918	0.727
		272.16	12.00	1.5208	2.1875	1.915	0.726
		329.76	12.00	1.6042	2.8336	1.595	0.723
		338.40	12.00	1.6875	2.9305	1.883	0.709
1-D	A	108.00	12.00	1.0833	0.2668	2.292	0.780
		132.48	12.00	1.1667	0.5119	2.221	0.765
		139.68	12.00	1.2083	0.5839	2.171	0.754
		156.96	12.00	1.2708	0.7569	2.124	0.743
		181.44	12.00	1.3542	1.0019	2.074	0.730
		190.08	12.00	1.3958	1.0884	2.039	0.721
		205.92	12.00	1.4375	1.2469	2.029	0.716

Table A2. Analysis Results (Series 1-E ~ 2-A)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
1-E	A	1396.68	12.00	1.0625	0.7274	1.834	0.804
		148.32	12.00	1.1042	0.8140	1.790	0.796
		197.28	12.00	1.1875	0.3052	1.801	0.779
		198.72	12.00	1.3125	1.3197	1.633	0.752
		205.92	12.00	1.4167	1.3919	1.529	0.730
		239.04	12.00	1.5000	1.7242	1.517	0.716
		247.68	12.00	1.5833	1.8109	1.455	0.701
		256.32	12.00	1.6250	1.8975	1.435	0.695
		272.16	12.00	1.6875	2.0564	1.413	0.685
		280.80	12.00	1.7708	2.1431	1.363	0.670
		289.44	12.00	1.8125	2.2298	1.347	0.660
		296.64	12.00	1.8958	2.3020	1.300	0.645
		338.40	12.00	2.0208	2.7210	1.288	0.632
		347.04	12.00	2.1667	2.8077	1.215	0.602
2-A	A	74.88	12.50	1.1250	0.5170	2.066	0.862
		90.72	12.50	1.1667	0.7185	2.041	0.855
		115.20	12.50	1.2292	1.0298	2.010	0.843
		181.44	12.50	1.3542	1.8724	2.002	0.830
		190.08	12.50	1.4167	1.9823	1.936	0.816
		198.72	12.50	1.4792	2.0922	1.875	0.798
		214.56	12.50	1.5625	2.2936	1.812	0.780
		239.04	12.50	1.6458	2.6050	1.774	0.768
		256.32	12.50	1.7292	2.8248	1.725	0.754
		263.52	12.50	1.8125	2.9164	1.660	0.730
		272.16	12.50	1.8542	3.0263	1.640	0.724
		276.48	12.50	1.9375	3.0812	1.578	0.704

Table A3. Analysis Results (Series 2-B ~ 2-C)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
2-B	A	123.84	13.25	1.3333	0.9442	1.567	0.805
		139.68	13.25	1.3958	1.0925	1.531	0.788
		156.96	13.25	1.4375	1.2544	1.523	0.782
		165.60	13.25	1.4792	1.3353	1.498	0.773
		185.76	13.25	1.5208	1.5241	1.497	0.765
		205.92	13.25	1.6667	1.7129	1.403	0.735
		223.20	13.25	1.7500	1.8747	1.366	0.716
		239.04	13.25	1.8125	2.0230	1.346	0.705
		247.68	13.25	1.8750	2.1039	1.315	0.693
		263.52	13.25	1.9583	2.2523	1.283	0.679
		289.44	13.25	2.1250	2.4950	1.220	0.646
		305.28	13.25	2.2083	2.6433	1.195	0.634
		329.76	13.25	2.3750	2.8726	1.143	0.604
2-C	A	57.60	12.00	1.0208	0.3173	2.047	0.895
		73.44	12.00	1.0625	0.4783	2.017	0.885
		99.36	12.00	1.1250	0.7418	1.982	0.866
		123.84	12.00	1.2292	0.9907	1.881	0.837
		139.68	12.00	1.3125	1.1517	1.802	0.816
		156.96	12.00	1.3958	1.3273	1.736	0.796
		181.44	12.00	1.5000	1.5762	1.671	0.773
		205.92	12.00	1.6667	1.8250	1.553	0.738
		221.76	12.00	1.7708	1.9860	1.492	0.718
		230.40	12.00	1.8333	2.0738	1.457	0.701
		239.04	12.00	1.8958	2.1617	1.424	0.688
		247.68	12.00	1.9583	2.2495	1.393	0.677
		288.00	12.00	2.1250	2.6593	1.348	0.648

Table A4. Analysis Results (Series 2-D ~ 2-E)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-max}}}$	α
2-D	A	99.36	12.50	1.1458	0.6511	1.856	0.855
		123.84	12.50	1.2083	0.8971	1.825	0.837
		148.32	12.50	1.2917	1.1432	1.768	0.820
		190.08	12.50	1.3750	1.5629	1.758	0.807
		221.76	12.50	1.4792	1.8813	1.703	0.787
		239.04	12.50	1.5625	2.0549	1.648	0.768
		254.88	12.50	1.6250	2.2141	1.615	0.759
		276.48	12.50	1.7083	2.4312	1.577	0.743
		288.00	12.50	1.8125	2.5470	1.507	0.721
		300.96	12.50	1.8750	2.6773	1.479	0.712
		321.12	12.50	1.9583	2.8799	1.449	0.699
2-E	A	67.68	13.00	1.1042	0.3956	2.064	0.866
		123.84	13.00	1.1667	0.9715	2.127	0.857
		156.96	13.00	1.2500	1.3111	2.080	0.837
		182.88	13.00	1.3333	1.5769	2.020	0.821
		194.40	13.00	1.4375	1.6950	1.903	0.795
		216.00	13.00	1.5000	1.9165	1.875	0.780
		233.28	13.00	1.5833	2.0937	1.816	0.766
		246.24	13.00	1.6667	2.2265	1.753	0.749
		270.72	13.00	1.7500	2.4776	1.720	0.735
		290.88	13.00	1.8333	2.6843	1.682	0.720
		302.40	13.00	1.9167	2.8024	1.630	0.704

Table A5. Analysis Results (Series 2-F ~ 3-A)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
2-F	A	93.60	16.00	1.4167	0.3774	1.423	0.760
		122.40	16.00	1.5000	0.6670	1.402	0.743
		141.12	16.00	1.5833	0.8553	1.365	0.727
		161.28	16.00	1.6667	1.0580	1.333	0.713
		181.44	16.00	1.7708	1.2607	1.290	0.695
		205.92	16.00	1.8333	1.5069	1.287	0.684
		221.76	16.00	1.9167	1.6662	1.256	0.670
		239.04	16.00	2.0000	1.8400	1.230	0.657
		257.76	16.00	2.0833	2.0282	1.208	0.646
		267.84	16.00	2.1667	2.1296	1.176	0.626
		286.56	16.00	2.2708	2.3178	1.148	0.610
		296.64	16.00	2.3333	2.4192	1.130	0.598
3-A	A	109.44	14.75	1.2500	0.7695	2.055	0.882
		129.60	14.75	1.3125	0.9747	2.007	0.866
		148.32	14.75	1.3958	1.1653	1.931	0.846
		158.40	14.75	1.4792	1.2679	1.845	0.826
		185.76	14.75	1.5833	1.5465	1.780	0.804
		195.84	14.75	1.6458	1.6491	1.732	0.791
		217.44	14.75	1.7292	1.8690	1.689	0.777
		241.92	14.75	1.8125	2.1182	1.656	0.759
		256.32	14.75	1.8958	2.2648	1.608	0.745
		270.72	14.75	1.9792	2.4114	1.564	0.729
		282.24	14.75	2.0625	2.5287	1.519	0.712
		293.76	14.75	2.1458	2.6460	1.477	0.696

Table A6. Analysis Results (Series 3-B ~ 3-C)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
3-B	A	50.40	13.50	1.1667	0.3400	2.008	0.913
		69.12	13.50	1.2083	0.5173	1.987	0.898
		82.08	13.50	1.2917	0.6400	1.893	0.874
		108.00	13.50	1.3750	0.8855	1.839	0.854
		129.60	13.50	1.4583	1.0900	1.781	0.834
		169.92	13.50	1.6250	1.4719	1.678	0.793
		185.76	13.50	1.7083	1.6219	1.626	0.774
		221.76	13.50	1.8750	1.9628	1.544	0.740
		234.72	13.50	1.9583	2.0856	1.499	0.724
		247.68	13.50	2.0417	2.2083	1.458	0.710
		259.20	13.50	2.1250	2.3174	1.419	0.690
		272.16	13.50	2.2500	2.4401	1.358	0.665
		282.24	13.50	2.3333	2.5356	1.324	0.645
3-C	A	87.84	12.00	1.0833	0.5171	2.063	0.927
		105.12	12.00	1.1667	0.6734	1.959	0.904
		123.84	12.00	1.2500	0.8427	1.872	0.879
		144.00	12.00	1.3333	1.0251	1.799	0.859
		158.40	12.00	1.4167	1.1553	1.723	0.840
		174.24	12.00	1.5000	1.2985	1.658	0.816
		182.88	12.00	1.5833	1.3767	1.587	0.798
		205.92	12.00	1.7500	1.5851	1.474	0.762
		230.40	12.00	1.9167	1.8065	1.383	0.727
		253.44	12.00	2.0833	2.0148	1.305	0.696
		280.80	12.00	2.2708	2.2623	1.232	0.660
		290.88	12.00	2.3333	2.3534	1.212	0.648
		300.96	12.00	2.4167	2.4446	1.182	0.634

Table A7. Analysis Results (Series 3-D ~ 4-B)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
3-D	A	70.56	13.00	1.1667	0.3433	1.981	0.902
		90.72	13.00	1.2500	0.5497	1.899	0.877
		109.44	13.00	1.3333	0.7414	1.823	0.857
		135.36	13.00	1.4167	1.0068	1.773	0.840
		149.76	13.00	1.50000	1.1543	1.704	0.815
		165.60	13.00	1.5833	1.3165	1.645	0.798
		184.32	13.00	1.6667	1.5082	1.597	0.784
		213.12	13.00	1.7500	1.8031	1.572	0.768
		226.08	13.00	1.8333	1.9358	1.522	0.749
		240.48	13.00	1.9167	2.0833	1.479	0.735
		250.56	13.00	2.0000	2.1865	1.433	0.718
		266.40	13.00	2.0833	2.3487	1.400	0.705
		279.36	13.00	2.1667	2.4814	1.364	0.685
		298.08	13.00	2.2500	2.6731	1.339	0.674
4-B	A	181.44	36.00	3.1042	0.0000	0.362	0.316
		201.60	36.00	3.1667	0.0000	0.366	0.318
		207.36	36.00	3.2500	0.0000	0.360	0.307
		224.64	36.00	3.3542	0.1325	0.358	0.299
		226.08	36.00	3.4167	0.1439	0.352	0.290
		243.36	36.00	3.5000	0.2802	0.352	0.285
		252.00	36.00	3.5833	0.3484	0.348	0.277
		269.28	36.00	3.6875	0.4848	0.347	0.270
		286.56	36.00	3.7500	0.6211	0.349	0.270
		306.72	36.00	3.8333	0.7802	0.351	0.268
		321.12	36.00	3.9167	0.8939	0.350	0.265
		328.32	36.00	4.0208	0.9507	0.344	0.252

Table A8. Analysis Results (Series 4-C ~ 4-E)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
4-C	A	194.40	36.00	3.0417	0.1707	0.420	0.335
		213.12	36.00	3.0833	0.3298	0.426	0.337
		243.36	36.00	3.1667	0.5867	0.434	0.338
		259.20	36.00	3.2500	0.7213	0.432	0.334
		280.80	36.00	3.3333	0.9048	0.434	0.330
		290.88	36.00	3.4167	0.9905	0.430	0.320
		305.28	36.00	3.5000	1.1128	0.428	0.313
		319.68	36.00	3.5833	1.2352	0.426	0.307
4-D	A	194.40	36.00	3.0417	0.2320	0.427	0.334
		201.60	36.00	3.0833	0.3074	0.426	0.329
		224.64	36.00	3.1667	0.5483	0.430	0.327
		241.92	36.00	3.2500	0.7291	0.429	0.323
		262.08	36.00	3.3333	0.9399	0.431	0.320
		275.04	36.00	3.4167	1.0755	0.428	0.310
		295.20	36.00	3.5000	1.2863	0.429	0.307
		303.84	36.00	3.5833	1.3767	0.424	0.298
4-E	A	195.84	36.00	3.0833	0.0000	0.393	0.327
		218.88	36.00	3.1875	0.1549	0.393	0.323
		230.40	36.00	3.2500	0.2592	0.392	0.320
		247.68	36.00	3.3333	0.4155	0.392	0.315
		257.76	36.00	3.4167	0.5067	0.388	0.304
		270.72	36.00	3.5208	0.6240	0.384	0.296
		282.24	36.00	3.5833	0.7282	0.383	0.291
		296.64	36.00	3.6667	0.8585	0.382	0.285
		306.72	36.00	3.7500	0.9497	0.378	0.277
		313.92	36.00	3.8333	1.0149	0.373	0.271

Table A9. Analysis Results (Series 5-B ~ 6-B)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
5-B	A	28.80	36.00	3.0083	0.0250	0.345	0.237
		47.50	36.00	3.0167	0.0667	0.358	0.249
		80.60	36.00	3.0333	0.1250	0.379	0.266
		138.20	36.00	3.0333	0.1917	0.420	0.302
		185.80	36.00	3.0417	0.3333	0.453	0.329
		229.00	36.00	3.1167	0.5417	0.472	0.340
		243.40	36.00	3.1667	0.7083	0.475	0.338
		262.10	36.00	3.2167	0.9167	0.480	0.340
		276.50	36.00	3.2583	1.1250	0.483	0.337
		295.20	36.00	3.3167	1.3333	0.487	0.337
5-C	A	224.60	36.00	3.0417	0.2500	0.437	0.352
		243.40	36.00	3.1583	0.3583	0.433	0.341
		275.00	36.00	3.2917	0.6917	0.434	0.335
5-D	A	217.40	36.00	3.0333	0.2083	0.446	0.349
		236.20	36.00	3.0750	0.5417	0.452	0.351
		247.70	36.00	3.1167	0.5833	0.453	0.349
		276.50	36.00	3.2750	0.7917	0.449	0.337
		301.00	36.00	3.4000	1.0417	0.447	0.327
6-A	A	226.10	36.00	3.1167	0.2083	0.530	0.441
		282.20	36.00	3.5083	0.5417	0.500	0.395
		331.20	36.00	3.8750	0.8333	0.476	0.335
6-B	A	257.80	36.00	3.4083	0.1667	0.470	0.404
		257.80	36.00	3.6500	0.3333	0.439	0.359
		260.60	36.00	3.6500	0.3750	0.441	0.359
		337.00	36.00	4.0000	0.7083	0.435	0.337

Table A10. Analysis Results (Series 6-C ~ 7-B)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-max}}}$	α
6-C	A	200.20	36.00	3.2083	0.2083	0.524	0.412
		266.40	36.00	3.3000	0.4583	0.549	0.424
		285.10	36.00	3.3750	0.6667	0.547	0.418
		328.30	36.00	3.6500	0.9167	0.529	0.388
6-D	A	256.30	36.00	3.4417	0.3333	0.499	0.395
		276.50	36.00	3.5833	0.6667	0.490	0.377
		308.20	36.00	3.7083	0.9167	0.489	0.370
7-A	A	216.00	36.00	3.0833	0.4938	0.572	0.393
		226.08	36.00	3.1667	0.5236	0.564	0.384
		237.60	36.00	3.2500	0.5613	0.558	0.374
		257.76	36.00	3.3333	0.6446	0.556	0.371
		273.60	36.00	3.3750	0.7467	0.561	0.368
		283.68	36.00	3.4500	0.8806	0.556	0.362
		295.20	36.00	3.5042	0.9451	0.555	0.355
		302.40	36.00	3.5917	0.9698	0.546	0.345
		316.80	36.00	3.6833	1.0244	0.541	0.340
7-B	A	214.56	35.88	3.0317	0.7786	0.542	0.404
		216.00	35.88	3.0608	0.7848	0.538	0.401
		223.20	35.88	3.0900	0.8279	0.538	0.396
		234.72	35.88	3.1067	0.9328	0.543	0.398
		239.04	35.88	3.1400	0.9513	0.540	0.393
		243.36	35.88	3.1733	0.9821	0.537	0.391
		249.12	35.88	3.2067	1.0253	0.536	0.387
		253.44	35.88	3.2400	1.0561	0.533	0.380
		263.52	35.88	3.2650	1.1301	0.535	0.382
		296.64	35.88	3.3067	1.6358	0.550	0.390

Table A11. Analysis Results (Series 7-C ~ 8-B)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
7-C	A	201.60	36.00	3.0208	0.2251	0.493	0.402
		204.48	36.00	3.0833	0.2266	0.485	0.388
		213.12	36.00	3.1667	0.2559	0.477	0.377
		237.60	36.00	3.2917	0.3423	0.474	0.370
		256.32	36.00	3.3333	0.3978	0.479	0.371
		267.84	36.00	3.4250	0.4378	0.472	0.360
		282.24	36.00	3.5000	0.5118	0.470	0.354
		286.56	36.00	3.5333	0.5180	0.468	0.349
7-D	A	213.12	35.40	2.9917	0.2837	0.520	0.412
		216.00	35.40	3.0583	0.2868	0.511	0.402
		220.32	35.40	3.1167	0.2929	0.504	0.391
		227.52	35.40	3.2000	0.3022	0.496	0.377
		234.72	35.40	3.2833	0.3145	0.487	0.368
		259.20	35.40	3.3667	0.3207	0.490	0.366
		266.40	35.40	3.4083	0.4625	0.488	0.363
		275.04	35.40	3.4833	0.4903	0.483	0.354
		285.12	35.40	3.5667	0.5396	0.477	0.345
8-B	A	146.88	24.00	2.2000	0.2907	0.657	0.491
		149.76	24.00	2.2750	0.3177	0.639	0.473
		156.96	24.00	2.3583	0.3356	0.624	0.459
		164.16	24.00	2.4417	0.3715	0.609	0.440
		175.68	24.00	2.5167	0.4164	0.602	0.429
		195.84	24.00	2.6000	0.5152	0.602	0.423
		205.92	24.00	2.6833	0.5870	0.592	0.410
		214.56	24.00	2.7583	0.6409	0.584	0.401
		269.28	24.00	2.8667	1.3412	0.608	0.407

Table A12. Analysis Results (Series 8-C ~ 9-A)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
8-C	A	146.88	23.76	2.0800	0.1559	0.661	0.520
		158.40	23.76	2.1467	0.2118	0.653	0.505
		167.04	23.76	2.2300	0.2398	0.637	0.491
		175.68	23.76	2.3133	0.2584	0.623	0.477
		182.88	23.76	2.4217	0.2863	0.602	0.455
		194.40	23.76	2.4800	0.3981	0.598	0.448
		203.04	23.76	2.5550	0.4540	0.588	0.437
		218.88	23.76	2.6550	0.5844	0.580	0.424
		227.52	23.76	2.7467	0.6403	0.568	0.412
		241.92	23.76	2.8300	0.7335	0.563	0.401
		260.64	23.76	2.8967	0.8639	0.565	0.399
		273.60	23.76	2.9800	0.9571	0.559	0.390
		288.00	23.76	3.0633	1.0782	0.555	0.379
		305.28	23.76	3.1467	1.2552	0.552	0.374
9-A	A	177.12	24.00	2.2500	0.5997	0.620	0.560
		184.32	24.00	2.3333	0.6150	0.604	0.541
		192.96	24.00	2.4167	0.6457	0.589	0.527
		201.60	24.00	2.5000	0.6763	0.576	0.512
		211.68	24.00	2.5833	0.7070	0.565	0.498
		221.76	24.00	2.6667	0.7377	0.554	0.485
		230.40	24.00	2.7500	0.7683	0.544	0.470
		246.24	24.00	2.8333	0.8296	0.538	0.460
		309.60	24.00	3.2000	2.2857	0.514	0.413
		316.80	24.00	3.5000	2.3470	0.473	0.362
		326.88	24.00	3.6667	2.3930	0.547	0.337
		341.28	24.00	3.8333	2.4390	0.444	0.318

Table A13. Analysis Results (Series 9-C ~ 9-D)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
9-C	A	148.32	23.88	2.1150	0.1872	0.742	0.577
		152.64	23.88	2.1567	0.2048	0.732	0.571
		164.16	23.88	2.2983	0.2401	0.698	0.540
		171.36	23.88	2.3650	0.2842	0.685	0.527
		177.12	23.88	2.4317	0.3018	0.671	0.516
		185.76	23.88	2.4900	0.3371	0.663	0.505
		192.96	23.88	2.5483	0.3635	0.654	0.498
		201.60	23.88	2.6150	0.4341	0.645	0.484
		216.00	23.88	2.6983	0.6104	0.637	0.474
		244.80	23.88	2.8150	1.0777	0.633	0.463
		257.76	23.88	2.8983	1.1218	0.624	0.454
		266.40	23.88	2.9817	1.1483	0.613	0.441
		288.00	23.88	3.1233	1.2453	0.601	0.421
9-D		162.72	23.52	2.0017	0.6425	0.955	0.618
		169.92	23.52	2.0767	0.6603	0.929	0.601
		180.00	23.52	2.1850	0.7049	0.895	0.576
		185.76	23.52	2.2350	0.7317	0.882	0.570
		190.08	23.52	2.2767	0.7584	0.871	0.562
		204.48	23.52	2.3683	0.8387	0.853	0.545
		214.56	23.52	2.4683	0.9189	0.829	0.527
		250.56	23.52	2.6267	1.4985	0.815	0.510
		296.64	23.52	2.7350	2.0424	0.827	0.505

Table A14. Analysis Results (Series 10-A ~ 10-E)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
10-A	A	158.40	24.24	2.2283	0.2750	0.877	0.609
		172.80	24.24	2.3700	0.3000	0.839	0.580
		187.20	24.24	2.5033	0.3583	0.808	0.555
		201.60	24.24	2.6033	0.4083	0.790	0.540
		216.00	24.24	2.6867	0.4833	0.778	0.526
		230.40	24.24	2.7867	0.5667	0.763	0.513
		244.80	24.24	2.8700	0.6750	0.752	0.499
		273.60	24.24	2.9533	1.0917	0.754	0.496
		302.40	24.24	2.9617	1.5417	0.775	0.505
		316.80	24.24	3.0450	1.6500	0.765	0.495
10-B	A	148.30	23.88	2.0600	0.3900	0.863	0.648
		158.40	23.88	2.2400	0.4000	0.804	0.610
		172.80	23.88	2.3700	0.4300	0.773	0.582
		201.60	23.88	2.4900	0.6100	0.761	0.565
		216.00	23.88	2.5700	0.7400	0.749	0.552
		244.80	23.88	2.7400	0.9900	0.726	0.529
		288.00	23.88	3.0700	1.1700	0.678	0.477
		305.30	23.88	3.2400	1.2900	0.654	0.451
10-E	A	165.60	24.48	2.1200	0.5600	0.912	0.641
		172.80	24.48	2.2100	0.5700	0.882	0.621
		199.40	24.48	2.4600	0.6400	0.817	0.571
		208.80	24.48	2.5400	0.6800	0.800	0.557
		223.20	24.48	2.6200	0.7600	0.789	0.545
		259.20	24.48	2.7500	1.1500	0.782	0.530
		273.60	24.48	2.9000	1.2300	0.753	0.509
		288.00	24.48	3.0400	1.3200	0.729	0.484

Table A15. Analysis Results (Series 11-A ~ 11-D)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
11-A	B	108.00	12.00	1.4200	0.1400	0.922	0.729
		158.40	12.00	1.6400	0.6900	0.886	0.701
		172.80	12.00	1.7300	0.7700	0.864	0.680
		190.10	12.00	1.8800	0.8500	0.821	0.651
		244.80	12.00	2.8000	1.1200	0.607	0.465
		259.20	12.00	2.9000	1.1600	0.600	0.452
		295.20	12.00	3.0800	1.4000	0.599	0.438
		316.80	12.00	3.1900	1.5200	0.597	0.427
11-B	B	86.40	12.00	1.0600	0.3700	1.491	0.849
		106.56	12.00	1.0800	0.7200	1.531	0.860
		133.92	12.00	1.1900	1.0200	1.472	0.841
		144.00	12.00	1.2500	1.0600	1.431	0.821
		148.32	12.00	1.2900	1.1100	1.399	0.812
		165.60	12.00	1.3300	1.3300	1.403	0.810
		180.00	12.00	1.5000	1.3900	1.279	0.766
		194.40	12.00	1.7500	1.4300	1.126	0.701
		216.00	12.00	1.9200	1.5400	1.067	0.666
		230.40	12.00	2.0800	1.6300	1.010	0.634
		273.60	12.00	2.2500	2.1300	1.003	0.620
11-D	B	72.00	12.12	1.0400	0.2700	1.593	0.852
		128.16	12.12	1.0900	1.1000	1.721	0.880
		144.00	12.12	1.1500	1.1300	1.685	0.859
		158.40	12.12	1.2600	1.2300	1.583	0.826
		178.56	12.12	1.2600	1.5500	1.646	0.840
		191.52	12.12	1.3400	1.5900	1.585	0.818
		207.36	12.12	1.4300	1.6800	1.529	0.799

Table A16. Analysis Results (Series 12-B ~ 12-D)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
12-B	B	72.00	12.00	1.0200	0.5200	2.222	0.948
		79.20	12.00	1.0800	0.5600	2.133	0.927
		86.40	12.00	1.1300	0.5800	2.071	0.912
		100.80	12.00	1.1700	0.6100	2.062	0.891
		154.08	12.00	1.2100	1.5100	2.218	0.918
		164.16	12.00	1.2700	1.5400	2.154	0.901
		236.16	12.00	1.3700	2.4200	2.263	0.898
		244.80	12.00	1.4200	2.4300	2.215	0.882
		259.20	12.00	1.5000	2.4500	2.145	0.860
		270.72	12.00	1.5800	2.4800	2.074	0.841
		296.64	12.00	1.7500	2.5700	1.948	0.801
12-C	B	80.64	12.00	1.4200	0.1500	0.814	0.798
		110.88	12.00	1.5000	0.4200	0.821	0.787
		141.12	12.00	1.6100	0.6800	0.813	0.768
		244.80	12.00	3.6400	1.3700	0.432	0.351
		273.60	12.00	3.8300	1.4200	0.430	0.338
		285.12	12.00	3.8900	1.4400	0.431	0.334
12-D	B	74.88	12.00	1.0800	0.2000	1.807	0.901
		110.88	12.00	1.1800	0.5700	1.787	0.882
		115.20	12.00	1.2300	0.6100	1.729	0.873
		129.60	12.00	1.3300	0.6600	1.858	0.841
		172.80	12.00	1.5200	1.0900	1.749	0.807
		217.44	12.00	1.6700	1.7300	1.708	0.791
		246.24	12.00	1.8300	1.8500	1.627	0.759
		279.36	12.00	1.9000	2.1500	1.643	0.757
		295.20	12.00	1.9800	2.3200	1.612	0.745

Table A17. Analysis Results (Series 14-A ~ 15-A)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
14-A	B	125.80	24.80	2.0900	0.2500	0.762	0.555
		133.92	24.80	2.1300	0.2700	0.761	0.560
		144.00	24.80	2.1700	0.3800	0.762	0.548
		172.80	24.80	2.3200	0.4900	0.755	0.526
		195.84	24.80	2.3800	0.7200	0.768	0.527
		201.60	24.80	2.4300	0.7600	0.760	0.520
		207.36	24.80	2.4800	0.8200	0.752	0.512
		230.40	24.80	2.5200	1.1100	0.771	0.520
		259.20	24.80	2.5800	1.4900	0.790	0.524
		273.60	24.80	2.6300	1.6400	0.794	0.523
14-B	B	190.08	22.50	2.4200	0.2500	0.601	0.510
		201.60	22.50	2.5400	0.2900	0.585	0.490
		230.40	22.50	2.7400	0.3800	0.570	0.465
		259.20	22.50	2.8400	0.5000	0.578	0.462
		285.12	22.50	2.8800	0.8100	0.594	0.471
		302.40	22.50	3.1300	0.8900	0.561	0.430
		316.80	22.50	3.2900	0.9800	0.546	0.409
		336.96	22.50	3.4600	1.1500	0.534	0.390
15-A	B	138.24	24.00	2.0200	0.2200	0.759	0.649
		159.84	24.00	2.1700	0.5100	0.738	0.624
		172.80	24.00	2.2500	0.5500	0.730	0.610
		195.84	24.00	2.4200	0.6600	0.708	0.580
		208.80	24.00	2.5000	1.0200	0.702	0.571
		234.72	24.00	2.6700	1.2000	0.791	0.546
		276.48	24.00	2.7300	1.5000	0.821	0.559
		289.44	24.00	2.8300	1.5300	0.801	0.541

Table A18. Analysis Results (Series 15-C ~ 17-B)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
15-C	B	151.92	24.00	2.0300	0.5400	0.857	0.657
		188.64	24.00	2.3300	0.6300	0.793	0.599
		205.92	24.00	2.5000	0.6800	0.759	0.566
		227.52	24.00	2.6700	0.7600	0.735	0.540
		247.68	24.00	2.8300	0.8900	0.714	0.516
		280.80	24.00	3.000	1.2500	0.706	0.499
15-D	B	158.40	23.80	2.0800	0.4200	0.883	0.645
		172.80	23.80	2.1800	0.4700	0.863	0.629
		201.60	23.80	2.3300	0.7300	0.845	0.607
		218.88	23.80	2.4800	0.8100	0.815	0.579
		234.72	23.80	2.6500	0.9100	0.781	0.551
		259.20	23.80	2.8200	1.1900	0.761	0.526
		293.76	23.80	2.9300	1.4400	0.769	0.520
17-A	B	200.16	35.50	3.0000	0.2500	0.501	0.391
		218.88	35.50	3.1300	0.3100	0.497	0.377
		234.72	35.50	3.2100	0.4300	0.498	0.373
		253.44	35.50	3.2600	0.6900	0.506	0.376
		264.96	35.50	3.3300	0.8100	0.505	0.370
		288.00	35.50	3.3600	1.1300	0.519	0.380
17-B	B	197.28	36.10	3.1100	0.3700	0.441	0.366
		211.68	36.10	3.1800	0.4100	0.443	0.363
		223.20	36.10	3.2600	0.4400	0.440	0.357
		244.80	36.10	3.3800	0.5200	0.441	0.349
		252.00	36.10	3.4300	0.5600	0.440	0.345
		259.20	36.10	3.4700	0.6100	0.440	0.343
		273.60	36.10	3.7600	0.7500	0.415	0.304

Table A19. Analysis Results (Series 18-A ~ 18-E)

Test I.D.	Type of Pile	Suction Pressure (psf)	Initial Pile Penetration (inch)	Pile Penetration (ft)	Water Rise (ft)	$\frac{(P_s+F_b/A)D}{\gamma_b D_p D_{p\text{-}max}}$	α
18-A	B	210.40	35.50	3.0000	0.2200	0.582	0.457
		220.32	35.50	3.0800	0.3400	0.575	0.446
		234.00	35.50	3.1700	0.4000	0.571	0.435
		244.80	35.50	3.2100	0.4500	0.573	0.434
		254.88	35.50	3.2500	0.4900	0.574	0.430
		263.52	35.50	3.2900	0.5700	0.574	0.429
18-B	B	244.80	35.50	3.0000	0.5600	0.660	0.477
		254.88	35.50	3.0200	0.6500	0.666	0.479
		259.20	35.50	3.0300	0.7100	0.668	0.477
		270.72	35.50	3.0800	0.8000	0.668	0.476
		277.92	35.50	3.1300	0.8500	0.664	0.468
		288.00	35.50	3.1700	0.9800	0.665	0.465
		299.52	35.50	3.1900	1.1400	0.671	0.468
18-C	B	265.68	36.50	3.2100	0.5600	0.591	0.445
		273.60	36.50	3.2300	0.6200	0.594	0.446
		292.32	36.50	3.2700	0.8800	0.603	0.448
		303.84	36.50	3.3300	0.9700	0.601	0.443
		309.60	36.50	3.3800	1.0400	0.597	0.437
		316.80	36.50	3.4200	1.1300	0.595	0.434
18-E	B	244.80	35.90	3.2200	0.2700	0.571	0.430
		260.64	35.90	3.2800	0.4000	0.573	0.430
		269.28	35.90	3.3300	0.4800	0.572	0.424
		280.80	35.90	3.3700	0.6200	0.574	0.423
		293.76	35.90	3.4100	0.7200	0.578	0.423
		312.48	35.90	3.4500	0.9900	0.585	0.426

Model Test Results of Suction Pile Installation in Clay and Calibration of Mobilized Soil Cohesion Ratio (Series 1 – 8)

PILE DATA

Outside diameter of pile = 1.967 inches
Thickness = 0.127 inches
Length of pile = 10.546 inches
Weight of pile = 0.40126 lbs
Weight of pile plus attachments = 0.54201 lbs

Table – 1 Summary of Suction Pile Tests for Clay

Series	Vacuum Pressure (p_s)		Penetration (D_p)		S_u	β	p_s+F_b/A	$\frac{(p_s+F_b/A)\ D}{S_u\ D_p}$
	psi	psf	inch	feet	psf		psf	
1-A	0.8	-115.2	2	0.167	58.9	0.291	144.39	2.41
	1	-144.0	2.1	0.175	60.6	0.348	173.19	2.68
	1.1	-158.4	2.4	0.200	65.2	0.296	187.59	2.36
	1.3	-187.2	2.6	0.217	68.0	0.280	216.39	2.41
	1.6	-230.4	3.5	0.292	78.3	0.224	259.59	1.86
	1.7	-244.8	3.5	0.292	78.3	0.237	273.99	1.97
	2.1	-302.4	3.8	0.317	81.2	0.251	331.59	2.12
	2.6	-374.4	4.9	0.408	90.0	0.212	403.59	1.80
	2.9	-417.6	5.1	0.425	91.4	0.218	446.79	1.89
	3.1	-446.4	5.3	0.442	92.7	0.221	475.59	1.90
	3.3	-475.2	5.8	0.483	95.9	0.207	504.39	1.79
	3.5	-504.0	6.1	0.508	97.6	0.202	533.19	1.76
	3.7	-532.8	6.5	0.542	99.8	0.195	561.99	1.70
1-B	1.07	-154.1	2.9	0.242	72.3	0.223	183.27	1.72
	1.47	-211.7	3.4	0.283	79.8	0.232	240.87	1.75
	2.07	-298.1	3.6	0.300	82.9	0.268	327.27	2.16
	2.52	-362.9	4.5	0.375	96.5	0.229	392.07	1.78
	3.11	-447.8	5.1	0.425	105.6	0.221	477.03	1.74
	3.82	-550.1	5.9	0.492	117.8	0.210	579.27	1.64
	4.69	-675.4	7.0	0.583	134.4	0.198	704.55	1.47
1-C	0.9	-129.6	2.0	0.167	45.7	0.412	158.79	3.42
	1.2	-172.8	2.4	0.200	49.6	0.412	201.99	3.34
	1.8	-259.2	3.5	0.292	57.7	0.323	288.39	2.81
	2.2	-316.8	3.9	0.325	60.0	0.329	345.99	2.91
	2.7	-388.8	4.5	0.375	63.1	0.327	417.99	2.90
	3.2	-460.8	5.0	0.417	65.4	0.332	489.99	2.95
	4.0	-576.0	5.5	0.458	67.4	0.280	605.19	3.21
1-D	0.55	-79.2	1.8	0.150	43.4	0.310	108.39	2.73
	0.74	-106.6	2.3	0.192	48.7	0.279	135.75	2.39
	0.91	-131.0	2.5	0.208	50.5	0.298	160.23	2.50
	1.25	-180.0	3.5	0.292	57.7	0.245	209.19	2.04

	1.66	-239.0	4.4	0.367	62.6	0.235	268.23	1.92
	2.45	-352.8	5.8	0.483	68.6	0.223	381.99	1.89
	3.41	-491.0	7.0	0.583	72.6	0.235	520.23	2.01
	4.25	-612.0	7.9	0.658	75.2	0.240	641.19	2.12
	4.79	-689.8	8.0	0.667	75.5	0.270	718.95	2.34
2-A	3.75	-540.0	3.8	0.317	135.8	0.290	569.19	2.17
	4.64	-668.2	3.9	0.325	137.1	0.341	697.35	2.57
	5.11	-735.8	4.1	0.342	139.6	0.338	765.03	2.63
	5.62	-809.3	4.9	0.408	149.7	0.285	838.47	2.25
	6.06	-872.6	5.1	0.425	152.2	0.284	901.83	2.29
	6.30	-907.2	5.5	0.458	157.3	0.268	936.39	2.13
	6.98	-1005.1	6.6	0.550	171.2	0.220	1034.31	1.80
	7.47	-1075.7	7.0	0.583	176.2	0.218	1104.87	1.76
	7.78	-1120.3	7.6	0.633	183.8	0.198	1149.51	1.62
	7.88	-1134.7	7.9	0.658	187.6	0.188	1163.91	1.55
2-B	3.60	-518.4	3.5	0.292	119.0	0.345	547.59	2.59
	4.60	-662.4	4.4	0.367	133.0	0.304	691.59	2.33
	5.40	-777.6	5.0	0.417	143.3	0.280	806.79	2.22
	6.27	-902.9	6.3	0.525	168.4	0.220	932.07	1.73
	6.97	-1003.7	7.0	0.583	183.7	0.205	1032.87	1.58
	7.62	-1097.3	7.8	0.650	202.9	0.188	1126.47	1.40
2-C	3.40	-489.6	3.6	0.300	120.5	0.305	518.79	2.35
	3.98	-573.1	3.9	0.325	125.0	0.316	602.31	2.43
	4.76	-685.4	4.8	0.400	139.8	0.266	714.63	2.10
	5.29	-761.8	5.0	0.417	143.3	0.280	790.95	2.17
	6.39	-920.2	6.9	0.575	181.4	0.193	949.35	1.49
	6.88	-990.7	7.3	0.608	190.7	0.191	1019.91	1.44
2-D	2.31	-332.6	2.9	0.242	106.9	0.293	361.83	2.30
	3.25	-468.0	3.8	0.317	116.1	0.265	497.19	2.22
	4.10	-590.4	4.8	0.400	124.0	0.237	619.59	2.05
	4.78	-688.3	5.5	0.458	128.6	0.229	717.51	2.00
	5.32	-766.1	6.4	0.533	133.7	0.202	795.27	1.83
	6.09	-877.0	7.3	0.608	138.2	0.196	906.15	1.77
3-A	3.53	-508.3	4.9	0.411	105.9	0.218	537.51	2.03
	4.05	-583.2	5.1	0.423	107.5	0.237	612.39	2.21
	4.32	-622.1	5.6	0.469	113.9	0.220	651.27	2.00
	4.55	-655.2	5.9	0.493	117.3	0.213	684.39	1.94
	4.83	-695.5	6.5	0.538	124.2	0.202	724.71	1.78
	5.33	-767.5	7.5	0.623	138.2	0.185	796.71	1.52
3-B	1.46	-210.2	1.7	0.145	75.8	0.395	239.43	3.57
	2.08	-299.5	2.9	0.240	85.4	0.273	328.71	2.63
	2.50	-360.0	3.2	0.266	88.2	0.291	389.19	2.72
	3.02	-434.9	4.2	0.352	98.3	0.238	464.07	2.20
	3.65	-525.6	4.9	0.408	105.4	0.230	554.79	2.12
	4.17	-600.5	5.7	0.476	114.9	0.212	629.67	1.89
	4.77	-686.9	6.8	0.565	128.5	0.188	716.07	1.62
	5.27	-758.9	7.6	0.633	140.0	0.179	788.07	1.46
3-C	0.73	-105.1	3.1	0.259	58.8	0.170	134.31	1.45
	0.97	-139.7	3.3	0.273	60.3	0.195	168.87	1.68
	1.27	-182.9	3.6	0.296	63.1	0.216	212.07	1.86
	1.47	-211.7	4.0	0.335	67.7	0.209	240.87	1.74

	1.84	-265.0	4.3	0.358	70.4	0.224	294.15	1.91
	2.53	-364.3	5.2	0.437	79.6	0.220	393.51	1.86
	3.03	-436.3	6.3	0.522	89.5	0.199	465.51	1.64
	3.56	-512.6	7.8	0.653	104.9	0.163	541.83	1.30
	3.72	-535.7	7.9	0.660	105.7	0.168	564.87	1.33
3-D	0.60	-86.4	2.3	0.194	51.2	0.227	115.59	1.91
	1.00	-144.0	4.1	0.342	68.4	0.145	173.19	1.21
	1.51	-217.4	4.8	0.398	75.0	0.162	246.63	1.36
	2.15	-309.6	5.5	0.460	82.3	0.177	338.79	1.47
	2.50	-360.0	6.2	0.513	88.4	0.174	389.19	1.41
	3.00	-432.0	6.8	0.565	94.6	0.176	461.19	1.42
	3.57	-514.1	7.6	0.633	102.6	0.173	543.27	1.37
	3.85	-554.4	7.7	0.643	103.7	0.179	583.59	1.43
4-A	2.00	-288.0	3.1	0.260	108.8	0.205	317.19	1.84
	3.03	-436.3	3.9	0.326	127.7	0.220	465.51	1.83
	4.30	-619.2	4.5	0.375	144.0	0.241	648.39	1.97
	5.01	-721.4	4.6	0.381	146.0	0.271	750.63	2.21
	5.53	-796.3	4.9	0.404	154.6	0.265	825.51	2.17
	6.03	-868.3	5.4	0.453	174.3	0.237	897.51	1.86
	6.50	-936.0	5.6	0.467	180.0	0.241	965.19	1.88
	7.03	-1012.3	6.0	0.503	196.5	0.235	1041.51	1.73
	7.66	-1103.0	6.7	0.555	223.3	0.212	1132.23	1.50
	8.02	-1154.9	7.0	0.582	238.3	0.202	1184.07	1.40
	8.56	-1232.6	7.3	0.611	255.9	0.198	1261.83	1.32
	9.12	-1313.3	7.7	0.643	277.0	0.187	1342.47	1.24
	9.48	-1365.1	7.9	0.660	288.4	0.187	1394.31	1.20
4-B	2.00	-288.0	3.5	0.289	116.8	0.179	317.19	1.54
	3.07	-442.1	4.3	0.362	139.4	0.188	471.27	1.53
	4.36	-627.8	4.9	0.411	157.1	0.205	657.03	1.67
	5.00	-720.0	5.1	0.421	161.0	0.234	749.19	1.81
	5.56	-800.6	5.3	0.440	168.7	0.230	829.83	1.83
	6.15	-885.6	5.9	0.489	190.2	0.212	914.79	1.61
	6.65	-957.6	6.0	0.503	196.5	0.223	986.79	1.64
	7.23	-1041.1	6.3	0.526	208.0	0.220	1070.31	1.61
	8.01	-1153.4	6.9	0.572	232.5	0.207	1182.63	1.46
	8.53	-1228.3	7.2	0.601	249.7	0.201	1257.51	1.37
	9.00	-1296.0	7.5	0.621	262.2	0.199	1325.19	1.34
	9.59	-1381.0	7.9	0.660	288.4	0.188	1410.15	1.21
4-C	2.47	-355.7	3.2	0.267	110.5	0.238	384.87	2.14
	3.11	-447.8	3.8	0.316	124.6	0.232	477.03	1.99
	3.72	-535.7	4.0	0.332	129.5	0.255	564.87	2.16
	4.21	-606.2	4.4	0.365	140.5	0.252	635.43	2.03
	4.65	-669.6	4.9	0.411	157.1	0.218	698.79	1.78
	5.30	-763.2	5.8	0.480	186.0	0.188	792.39	1.46
	5.53	-796.3	5.8	0.486	188.6	0.196	825.51	1.48
	5.93	-853.9	6.3	0.523	206.3	0.182	883.11	1.34
	6.28	-904.3	6.8	0.565	228.8	0.166	933.51	1.18
	6.82	-982.1	7.5	0.628	266.5	0.149	1011.27	0.99
	7.29	-1049.8	7.8	0.650	281.5	0.149	1078.95	0.97
	7.37	-1061.3	8.0	0.667	293.2	0.146	1090.47	0.92
	2.12	-305.3	3.4	0.283	114.9	0.202	334.47	1.69

4-D	2.81	-404.6	3.9	0.326	127.7	0.204	433.83	1.71
	3.51	-505.4	4.4	0.365	140.5	0.213	534.63	1.71
	4.51	-649.4	5.3	0.443	170.1	0.190	678.63	1.48
	5.00	-720.0	5.4	0.447	171.5	0.209	749.19	1.60
	5.61	-807.8	6.0	0.496	193.3	0.190	837.03	1.43
	6.34	-913.0	6.8	0.568	230.7	0.168	942.15	1.18
	6.72	-967.7	7.2	0.601	249.7	0.160	996.87	1.09
	7.28	-1048.3	7.7	0.641	275.3	0.155	1077.51	1.00
	7.42	-1068.5	7.8	0.650	281.5	0.152	1097.67	0.98
	7.53	-1084.3	7.9	0.660	288.4	0.149	1113.51	0.96
5-A	0.47	-67.7	2.6	0.213	26.3	0.427	96.87	2.84
	0.72	-103.7	3.4	0.286	35.3	0.332	132.87	2.16
	1.00	-144.0	3.7	0.312	39.3	0.377	173.19	2.32
	1.49	-214.6	4.8	0.401	56.6	0.279	243.75	1.76
	2.05	-295.2	4.9	0.408	58.2	0.346	324.39	2.24
	2.53	-364.3	5.6	0.463	73.1	0.310	393.51	1.90
	2.94	-423.4	5.6	0.469	74.9	0.341	452.55	2.11
	3.44	-495.4	6.3	0.528	95.4	0.304	524.55	1.71
	4.12	-593.3	7.0	0.581	118.3	0.284	622.47	1.49
	4.54	-653.8	7.2	0.601	128.4	0.287	682.95	1.45
	5.13	-738.7	7.7	0.643	152.8	0.270	767.91	1.28
5-B	0.50	-72.0	2.8	0.233	28.5	0.380	101.19	2.49
	0.80	-115.2	3.7	0.306	38.4	0.326	144.39	2.02
	1.00	-144.0	4.0	0.332	42.6	0.315	173.19	2.01
	1.50	-216.0	5.0	0.417	60.4	0.260	245.19	1.60
	2.10	-302.4	5.4	0.453	70.2	0.274	331.59	1.71
	2.50	-360.0	6.0	0.499	84.7	0.260	389.19	1.51
	3.00	-432.0	6.5	0.545	102.2	0.246	461.19	1.36
	3.40	-489.6	6.7	0.562	109.4	0.252	518.79	1.38
	4.10	-590.4	7.7	0.643	152.8	0.220	619.59	1.03
	4.50	-648.0	7.9	0.660	163.6	0.227	677.19	1.03
5-C	1.20	-172.8	6.0	0.503	74.1	0.143	201.99	0.89
	1.50	-216.0	6.1	0.506	74.7	0.160	245.19	1.06
	2.10	-302.4	6.6	0.552	83.3	0.180	331.59	1.18
	2.50	-360.0	6.7	0.558	84.6	0.209	389.19	1.35
	2.90	-417.6	7.3	0.604	94.4	0.196	446.79	1.28
	3.20	-460.8	7.4	0.618	97.5	0.204	489.99	1.34
5-D	0.50	-72.0	3.01	0.251	40.7	0.237	101.19	1.63
	0.80	-115.2	3.72	0.310	46.8	0.240	144.39	1.63
	1.20	-172.8	4.51	0.376	54.8	0.232	201.99	1.61
	2.00	-288.0	5.29	0.441	64.0	0.262	317.19	1.84
	2.50	-360.0	5.84	0.487	71.4	0.263	389.19	1.84
	2.90	-417.6	6.20	0.517	76.6	0.270	446.79	1.85
	3.50	-504.0	6.91	0.576	88.3	0.254	533.19	1.72
6-A	0.50	-72.0	3.35	0.279	37.5	0.235	101.19	1.58
	0.90	-129.6	4.14	0.345	43.2	0.240	158.79	1.75
	1.50	-216.0	5.24	0.437	52.5	0.235	245.19	1.75
	2.10	-302.4	5.83	0.486	58.4	0.265	331.59	1.92
	2.60	-374.4	6.35	0.529	64.0	0.276	403.59	1.95
	3.00	-432.0	6.94	0.578	71.1	0.263	461.19	1.84
	3.30	-475.2	7.33	0.611	76.2	0.265	504.39	1.78

	3.90	-561.6	8.12	0.677	87.7	0.255	590.79	1.63
6-B	0.50	-72.0	3.47	0.289	38.3	0.220	101.19	1.50
	0.90	-129.6	4.34	0.362	44.8	0.226	158.79	1.61
	1.40	-201.6	4.85	0.404	49.0	0.254	230.79	1.91
	1.80	-259.2	5.40	0.450	54.1	0.271	288.39	1.94
	2.10	-302.4	5.72	0.477	57.2	0.277	331.59	1.99
	2.50	-360.0	6.15	0.513	61.8	0.279	389.19	2.02
	2.80	-403.2	6.70	0.558	68.1	0.270	432.39	1.86
	3.30	-475.2	7.41	0.618	77.3	0.255	504.39	1.73
	3.70	-532.8	7.92	0.660	84.6	0.252	561.99	1.65
	3.90	-561.6	8.12	0.677	87.7	0.255	590.79	1.63
6-C	0.50	-72.0	3.79	0.316	60.5	0.152	101.19	0.87
	1.00	-144.0	4.50	0.375	71.1	0.176	173.19	1.07
	1.50	-216.0	5.01	0.418	78.7	0.196	245.19	1.22
	2.00	-288.0	5.48	0.457	85.7	0.207	317.19	1.33
	2.50	-360.0	5.87	0.489	91.5	0.218	389.19	1.43
	3.00	-432.0	6.31	0.526	98.0	0.224	461.19	1.47
	3.40	-489.6	6.82	0.568	105.6	0.216	518.79	1.42
6-D	0.50	-72.0	3.31	0.276	53.3	0.193	101.19	1.13
	0.90	-129.6	4.38	0.365	69.3	0.176	158.79	1.03
	1.30	-187.2	4.69	0.391	73.9	0.199	216.39	1.23
	1.70	-244.8	4.97	0.414	78.1	0.216	273.99	1.39
	2.30	-331.2	6.03	0.503	93.9	0.198	360.39	1.25
	2.80	-403.2	6.74	0.562	104.5	0.184	432.39	1.21
	3.30	-475.2	6.82	0.568	105.6	0.212	504.39	1.38
	3.90	-561.6	7.25	0.604	112.0	0.215	590.79	1.43
	4.20	-604.8	7.57	0.631	116.8	0.212	633.99	1.41
	4.50	-648.0	7.88	0.657	121.4	0.207	677.19	1.39
	4.74	-682.6	8.08	0.673	124.4	0.209	711.75	1.39
7-A	0.50	-72.0	1.62	0.135	37.2	0.346	101.19	3.30
	0.80	-115.2	3.31	0.276	92.1	0.129	144.39	0.93
	1.30	-187.2	4.69	0.391	118.8	0.105	216.39	0.76
	1.80	-259.2	5.32	0.443	128.5	0.113	288.39	0.83
	2.20	-316.8	5.48	0.457	130.7	0.129	345.99	0.95
	2.70	-388.8	6.30	0.525	141.4	0.123	417.99	0.92
	3.20	-460.8	6.81	0.568	147.4	0.126	489.99	0.96
	3.60	-518.4	7.25	0.604	152.2	0.126	547.59	0.98
	4.00	-576.0	7.64	0.637	156.2	0.129	605.19	1.00
7-B	0.50	-72.0	1.66	0.138	39.1	0.346	101.19	3.07
	0.80	-115.2	2.76	0.230	78.1	0.202	144.39	1.32
	1.10	-158.4	3.51	0.293	96.6	0.154	187.59	1.09
	1.60	-230.4	4.33	0.361	112.7	0.146	259.59	1.05
	2.30	-331.2	5.36	0.447	129.1	0.141	360.39	1.03
	2.60	-374.4	5.79	0.483	135.0	0.137	403.59	1.02
	3.10	-446.4	6.50	0.542	143.8	0.130	475.59	1.00
	3.50	-504.0	7.17	0.598	151.4	0.124	533.19	0.97
	4.10	-590.4	7.80	0.650	157.8	0.127	619.59	0.99
	0.50	-72.0	1.58	0.132	122.1	0.104	101.19	1.03
	2.70	-388.8	2.37	0.198	142.0	0.262	417.99	2.44
	3.90	-561.6	2.88	0.240	151.6	0.276	590.79	2.66
	4.70	-676.8	3.74	0.312	164.4	0.245	705.99	2.26

7-C	5.80	-835.2	4.18	0.348	169.9	0.254	864.39	2.40
	6.80	-979.2	5.32	0.443	181.8	0.216	1008.39	2.05
	7.40	-1065.6	5.75	0.479	185.6	0.218	1094.79	2.02
	7.90	-1137.6	6.54	0.545	191.9	0.191	1166.79	1.83
	8.50	-1224.0	7.21	0.601	196.7	0.182	1253.19	1.74
	9.00	-1296.0	7.80	0.650	200.6	0.173	1325.19	1.67
7-D	1.00	-144.0	1.54	0.128	120.8	0.193	173.19	1.83
	2.20	-316.8	1.58	0.132	122.1	0.360	345.99	3.53
	3.00	-432.0	2.64	0.220	147.3	0.243	461.19	2.33
	4.30	-619.2	3.63	0.303	163.0	0.224	648.39	2.16
	5.20	-748.8	4.35	0.363	171.9	0.218	777.99	2.05
	5.70	-820.8	4.69	0.391	175.6	0.216	849.99	2.03
	6.30	-907.2	5.40	0.450	182.5	0.201	936.39	1.87
	7.00	-1008.0	6.34	0.528	190.4	0.179	1037.19	1.69
	7.70	-1108.8	7.05	0.588	195.6	0.166	1137.99	1.62
	8.00	-1152.0	7.84	0.653	200.8	0.152	1181.19	1.48
8-A	2.50	-360.0	3.20	0.267	142.6	0.160	389.19	1.68
	3.00	-432.0	3.28	0.273	143.3	0.184	461.19	1.93
	3.80	-547.2	3.67	0.306	147.0	0.205	576.39	2.10
	4.20	-604.8	3.83	0.319	148.5	0.215	633.99	2.19
	4.90	-705.6	4.46	0.372	154.5	0.204	734.79	2.10
	5.40	-777.6	4.81	0.401	157.8	0.205	806.79	2.09
	5.80	-835.2	5.40	0.450	163.3	0.196	864.39	1.93
	6.50	-936.0	5.87	0.489	167.8	0.193	965.19	1.93
	7.00	-1008.0	6.43	0.536	173.1	0.184	1037.19	1.83
	7.60	-1094.4	7.21	0.601	180.4	0.174	1123.59	1.70
	7.98	-1149.1	7.72	0.643	185.2	0.165	1178.31	1.62
	8.30	-1195.2	8.12	0.677	189.0	0.163	1224.39	1.57
8-B	1.70	-244.8	3.04	0.253	141.1	0.123	273.99	1.26
	3.00	-432.0	3.08	0.257	141.4	0.209	461.19	2.08
	4.00	-576.0	3.91	0.326	149.3	0.199	605.19	2.04
	4.60	-662.4	4.42	0.368	154.1	0.193	691.59	2.00
	5.20	-748.8	4.93	0.411	158.9	0.191	777.99	1.95
	5.50	-792.0	5.24	0.437	161.8	0.187	821.19	1.91
8-C	2.50	-360.0	4.30	0.358	109.0	0.177	389.19	1.63
	3.00	-432.0	5.09	0.424	120.0	0.163	461.19	1.49
	3.50	-504.0	5.44	0.453	124.9	0.173	533.19	1.54
	4.00	-576.0	5.91	0.493	131.4	0.174	605.19	1.53
	4.50	-648.0	6.35	0.529	137.6	0.179	677.19	1.53
	4.90	-705.6	6.90	0.575	145.2	0.168	734.79	1.44
	5.30	-763.2	7.29	0.608	150.6	0.170	792.39	1.42
	5.70	-820.8	8.12	0.677	162.2	0.154	849.99	1.27
8-D	1.50	-216.0	3.51	0.293	98.0	0.149	245.19	1.40
	2.10	-302.4	4.22	0.352	107.9	0.155	331.59	1.43
	2.70	-388.8	4.73	0.394	115.0	0.171	417.99	1.51
	3.10	-446.4	5.13	0.428	120.6	0.170	475.59	1.51
	3.60	-518.4	5.72	0.477	128.8	0.171	547.59	1.46
	4.10	-590.4	6.23	0.519	135.9	0.168	619.59	1.44
	4.50	-648.0	6.86	0.572	144.7	0.157	677.19	1.34
	4.80	-691.2	7.13	0.594	148.4	0.159	720.39	1.34
	5.00	-720.0	7.33	0.611	151.2	0.160	749.19	1.33

	5.20	-748.8	7.57	0.631	154.5	0.155	777.99	1.31
	5.50	-792.0	8.08	0.673	161.6	0.149	821.19	1.24

COMPARISON OF MOORING LINE FIELD TEST RESULTS

6. COMPARISON WITH FIELD TESTS

6.1 Summary of Field Tests

A series of field tests on drag embedment anchors were performed by the Naval Facilities Engineering Service Center (formerly the Naval Civil Engineering Laboratory) in Indian Island in Puget Sound, Washington (4).

The Indian Island seafloor consisted of normally consolidated soft silty clay with shell fragments and was classified as an organic silty clay of high plasticity. The particle size was almost evenly distributed between silt and clay. The liquid limit and water content values were relatively high and approximately equal, varying little with depth up to 28 feet. Values ranged from 110 to 160 for the water content and 117 to 142 for the liquid limit. The shear strength increased almost nearly from zero at the surface to 180 psf at 21 feet.

Figure - 45 shows the schematics of the test setup. The mooring line was pulled by a towing winch located on the barge, dragging the anchor under the seafloor. The instruments on the anchor, the mooring line, and the barge recorded the movements and tensions of the anchor and mooring line.

The details of the anchors and mooring lines used for the tests are listed in Table - 6. It describes the anchor type, the anchor weight and the mooring line details.

6.2 Verification

6.2.1 input

Major input data for the analytical comparison with field test results were the values of the horizontal tension at the buoy, water depth, depth to anchor from seafloor, and friction factor at the seafloor surface, in addition to the material and geometric parameters.

The seafloor soil strength was described by a linearly increasing rate with depth of 8.6 psf/ft, starting from zero strength at the surface. The friction factor describes the mooring line - soil interaction behavior at the seafloor surface.

The measured results from the field tests included the anchor force, the mooring line inclination at buoy, and the length of the mooring line on bottom. The length of the mooring line on bottom is the total length of the mooring line buried in the seafloor and lying on the seafloor surface. These were compared against the results from analytical solutions. The analytical solution used for this study includes modifications from the previous solution (3), considering the length of the mooring line that may lie on the seafloor surface.

The analytical solution describes the development of tangential and normal forces associated with the mooring line with the following parameters.

EWBc = Diameter Factor for Chain Bearing

EWBw = Diameter Factor for Cable Bearing

EWSc = Diameter Factor for Chain Sliding

EWSw = Diameter Factor for Cable Sliding

N_{cc} = Chain Bearing Capacity Factor

N_{cw} = Cable Bearing Capacity Factor

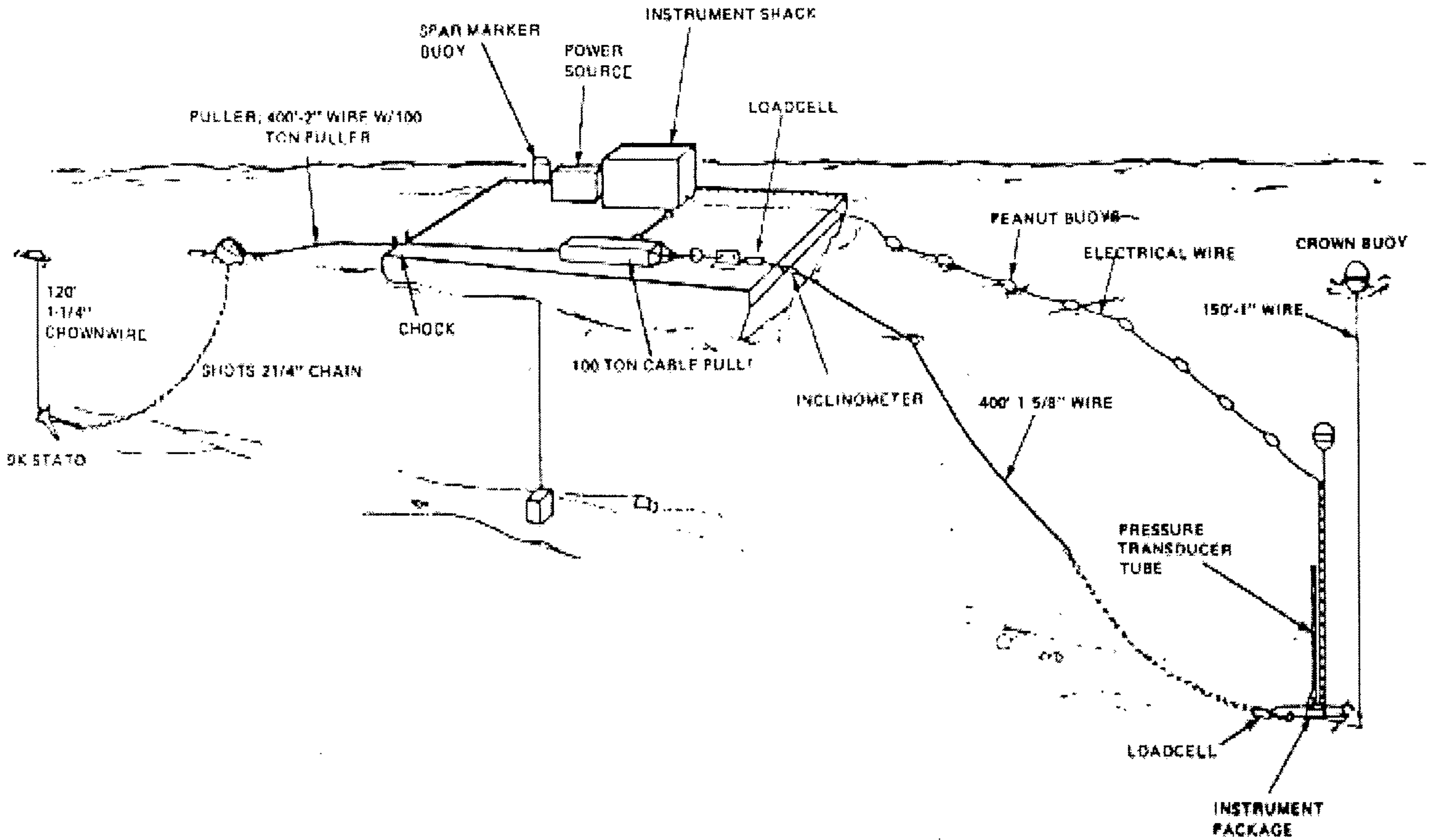


Figure - 45 Anchor Test Setup

TEST NO	SEAFLOOR TYPE	ANCHOR TYPE	ANCHOR WEIGHT	MOORING LINE DESCRIPTION
170-1	SILT	STATO	1070 LB	90 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
172-7	SILT	STOCKLESS	11370 LB	90 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
172-8	SILT	STOCKLESS	11370 LB	90 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
172-9	SILT	STOCKLESS	5950 LB	90 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
172-10	SILT	STOCKLESS	5950 LB	90 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
174-13	SILT	STOCKLESS	5950 LB	135 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
174-14	SILT	STOCKLESS	5950 LB	135 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
176-23	SILT	STATO	3500 LB	135 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
176-25	SILT	STATO	6600 LB	135 FT. 2 IN. C, 360 FT. 2.5 IN. C, 400 FT. 1 5/8 IN. W, 346 FT. 2 IN. W
208-5	SILTY CLAY	TWO FLUKE	9800 LB	180 FT. 2.0 IN. C, 270 FT. 3 IN. C
209-12	SILTY CLAY	STEVFIX	11000 LB	90 FT. 3.0 IN. C, 180 FT. 2.0 IN. C, 270 FT. 3 IN. C

Note : C = Chain, W = Wire

Table - 6 Description of Anchors and Mooring Lines of Indian Island Tests

α_c = Chain Slide Adhesion Factor

α_w = Cable Slide Adhesion Factor

DELc = Chain Slide Friction Factor for Buried Portion

DELw = Cable Slide Friction Factor for Buried Portion

δ_c = Chain Slide Friction Factor on Seafloor Surface

δ_w = Cable Slide Friction Factor on Seafloor Surface

β_c = Chain Slide Area Factor

β_w = Cable Slide Area Factor

Please refer the reference (2) for the detailed description of these parameters.

In the analytical solution, the tangential force developed along the mooring line segment buried within the seafloor is described based on the conventional Mohr – Coulomb shear strength theory, i.e.,

$$F = c\,l + N \tan\delta \tag{7}$$

where F = tangential force

c = soil cohesion

l = mooring line segment length

N = normal force

$\tan\delta$ = interface friction coefficient between the mooring line and the soil

The interface friction coefficient, $\tan\delta$, is expressed as a fraction of the soil internal friction coefficient, $\tan\phi$. This description of the tangential force has been found to be very representative for mooring line segments buried within the seafloor. However, the tangential force developed between the mooring line and the soil at the seafloor surface needs a special attention, particularly for saturated cohesive soils which follow the $\phi = 0$ behavior. Therefore, the surface friction factor between the mooring line and the soil is introduced to describe the tangential force developed along the mooring line lying on the seafloor surface, i.e.,

$$F = c\,l + N\,\Delta \tag{8}$$

where Δ = surface friction factor

The magnitude of the surface friction factor can be evaluated from the field test results as follows.

At the beginning of the test, the entire mooring line either lies on the seafloor surface or is suspended in the water. When the mooring line is tensioned, the sum of the force at the anchor and the friction force along the mooring line must equal to the horizontal tension applied at the deck (Figure – 46). Since the soil cohesion at zero depth is zero, the surface friction factor Δ can be calculated from Eq. (8), i.e.,

$$\Delta = \frac{F}{N} = \frac{\text{Deck Horizontal Tension} - \text{Anchor Force}}{\text{Total Weight of Mooring line on Seafloor Surface}} \tag{9}$$

Using the field measurements at the very beginning of the tests, the surface friction factors at the seafloor surface were obtained as shown in Table – 7

As described in the previous chapter, the centrifuge test results yielded the values of the chain bearing capacity factor (N_{cc}), the cable bearing capacity factor (N_{cw}), the chain sliding adhesion factor (α_c), and the cable sliding adhesion factor (α_w) associated with the clay. The values of N_{cc} and N_{cw} obtained from the centrifuge tests were used for the verification of the analytical solution with field test results. However, the values of α_c and α_w from the centrifuge tests were not used, since their magnitudes were rather large due to the effect of the chasing wires used in the tests. For this reason, the value of α obtained from the previous

study without considering the effect of chasing wires (3) was used in the verification. Table – 8 indicates the details of these factors together with the diameter conversion factors that are merely geometric conversion parameters used in the verification with field test results. Reference (2) explains in detail how the diameter conversion factors are obtained. It is noted that the chain/cable slide area factors (β) were assumed to remains 1.0 in the analysis. This is mainly because the tangential force developed at the bottom side of the mooring line is influenced by the product of α and β, and no attempt was made during the model tests to separate the effects of these two parameters.

The mooring line consists of three typical segments, as shown in Figure - 47; the embedded segment, i.e., the portion of mooring line completely buried within the seafloor; the mooring line segment lying on the surface of the seafloor; and the catenary segment, i.e., the mooring line suspended in the water.

6.2.2. comparisons

The results of field tests, except whose surface friction factors could not be determined due to insufficient field data, on the axial force at anchor, the mooring line inclination angle at buoy, and the mooring line length on bottom have been compared with the analytical

Test Number	Anchor Crown Depth (ft)	Water Depth (ft)	Deck Horizontal Force (lbs)	Anchor Force (lbs)	Deck Horiz. Force - Anc. Force (lbs)	Total Bottom Weight (lbs)	Surface Friction Factor
170-1	89.7	86.4	13400	2800	10600	21843.9	0.485
172-7	80.6	78.8	17300	2500	14800	20937	0.707
172-8	91.2	90.8	20300	3300	17000	20646.2	0.823
172-9	93.2	92.2	17500	200	17300	25801.9	0.670
172-10	92	92	23100	800	22300	25004.7	0.892
174-13	87.2	86.9	19600	No data	***	27198.4	***
174-14	88.9	88.9	22000	No data	***	26946.6	***
176-23	80.8	81.9	28700	600	28100	22979.8	1.223
176-25	93	89.3	41700	No data	***	23461.4	***
208-5	88	89	13800	7600	6200	20250.7	0.306
209-12	85.8	88	13200	100	13100	28303.1	0.463

Table – 7 Surface Friction Factors of Indian Island Tests

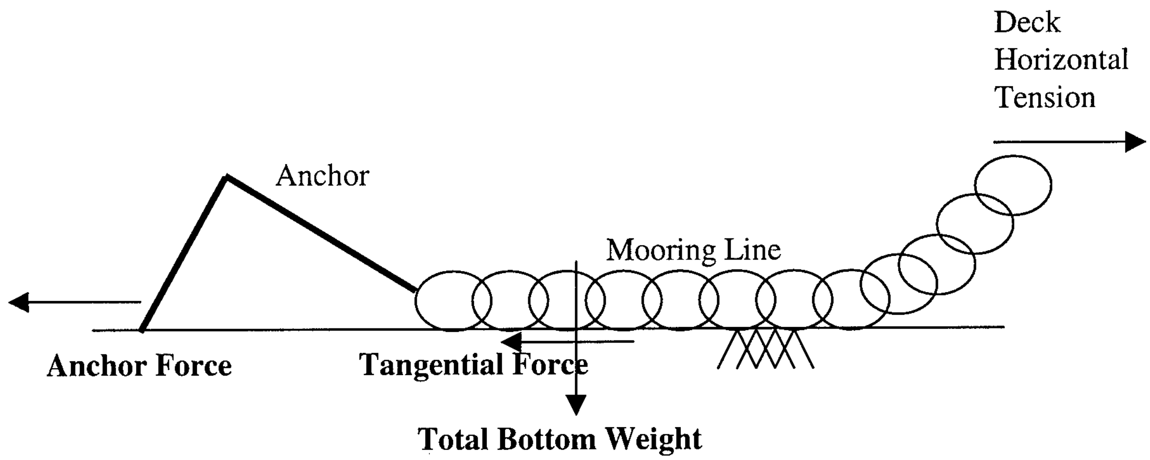


Figure – 46 Anchor and Mooring Line on Seafloor

Item	Value(unitless)
Diameter Factor for Chain Bearing (EWBc)	0.233
Diameter Factor for Cable Bearing (EWBw)	0.0833
Diameter Factor for Chain Sliding (EWSc)	0.733
Diameter Factor for Cable Sliding (EWSw)	0.2618
Chain Bearing Capacity Factor (N_{cc})	14
Cable Bearing Capacity Factor (N_{cw})	9
Chain Slide Adhesion Factor (α_c)	1.4
Cable Slide Adhesion Factor (α_w)	1.4

Table - 8 Constant Input Data of Indian Island Tests

predictions. Appendix - A includes the complete details of the comparisons between the measured and the predicted values of these three parameters.

Figures - 48 through 50 show the summary of comparisons between the measured and the predicted values. As can be seen from Figure - 48, the measured anchor forces agree very well with the analytical solutions. The mooring line inclination angles at buoy also show very good agreement between the measured and the calculated values, as shown in Figure - 49, for all tests. Figure – 50 indicates that the predicted values of the mooring line on bottom slightly overestimate the measured values. The discrepancy between the measured and the predicted values may be in part due to the variation in soil conditions at the test site. Additional study

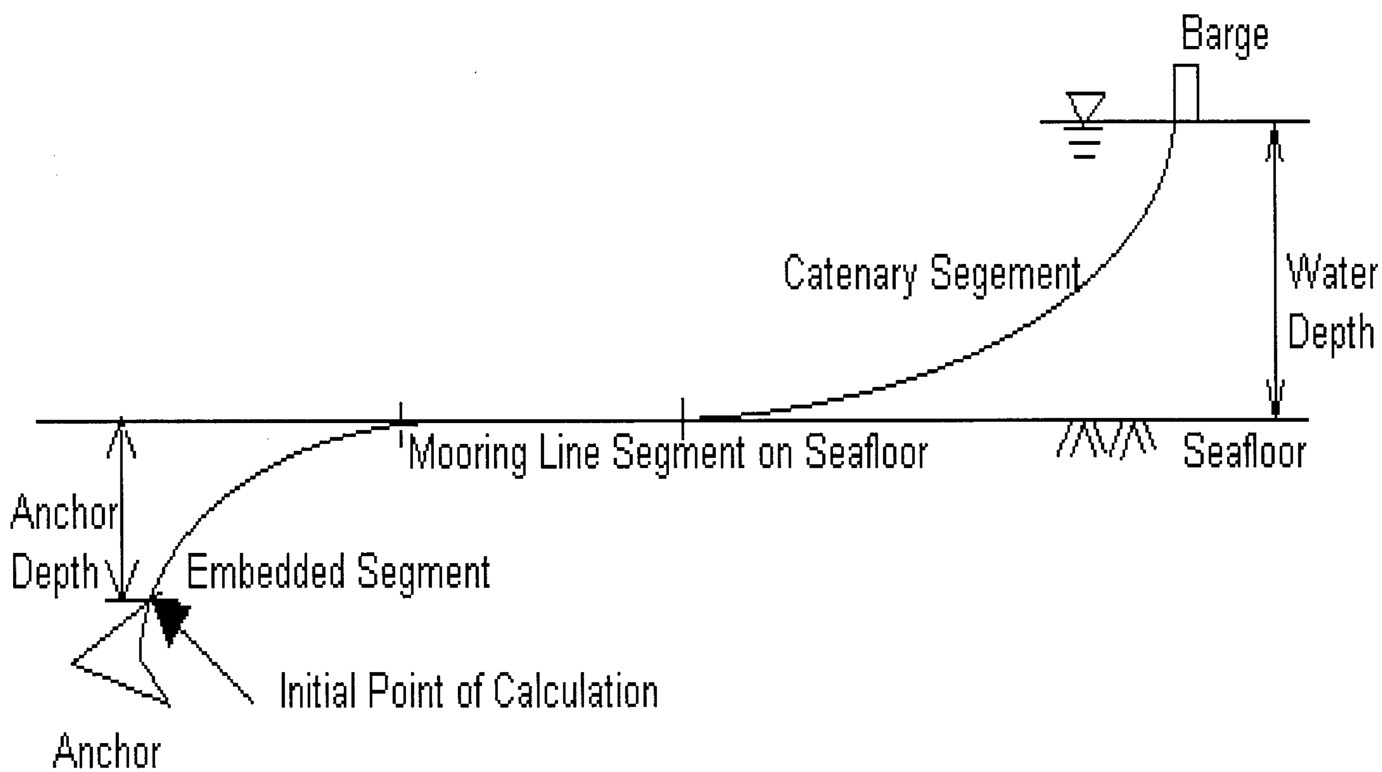


Figure - 47 Anchor - Mooring Line System

needs to be conducted in characterizing the load transfer mechanism at the seafloor surface to improve the accuracy of the analytical solution.

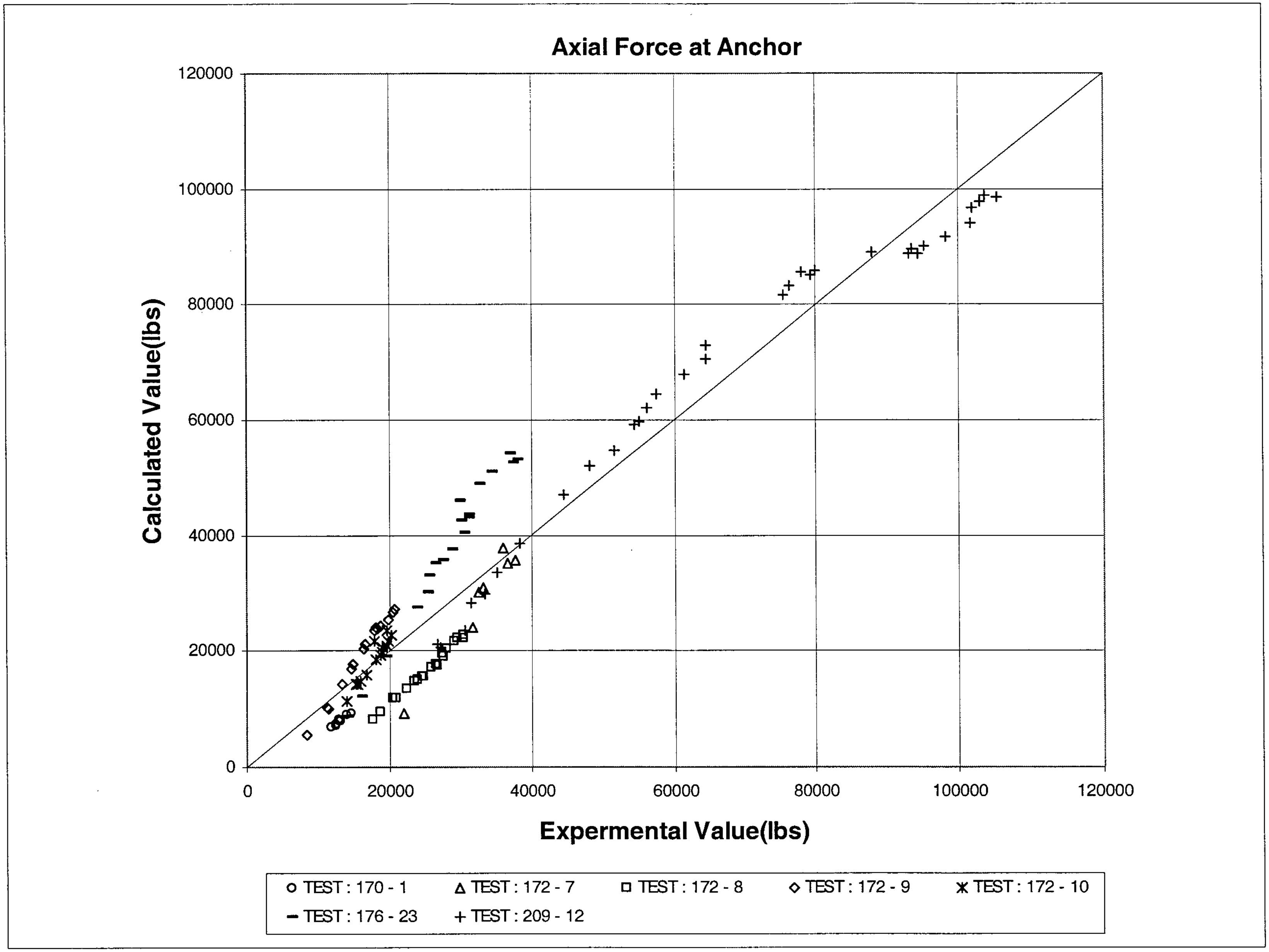


Figure – 48 Comparison of Axial Force at Anchor

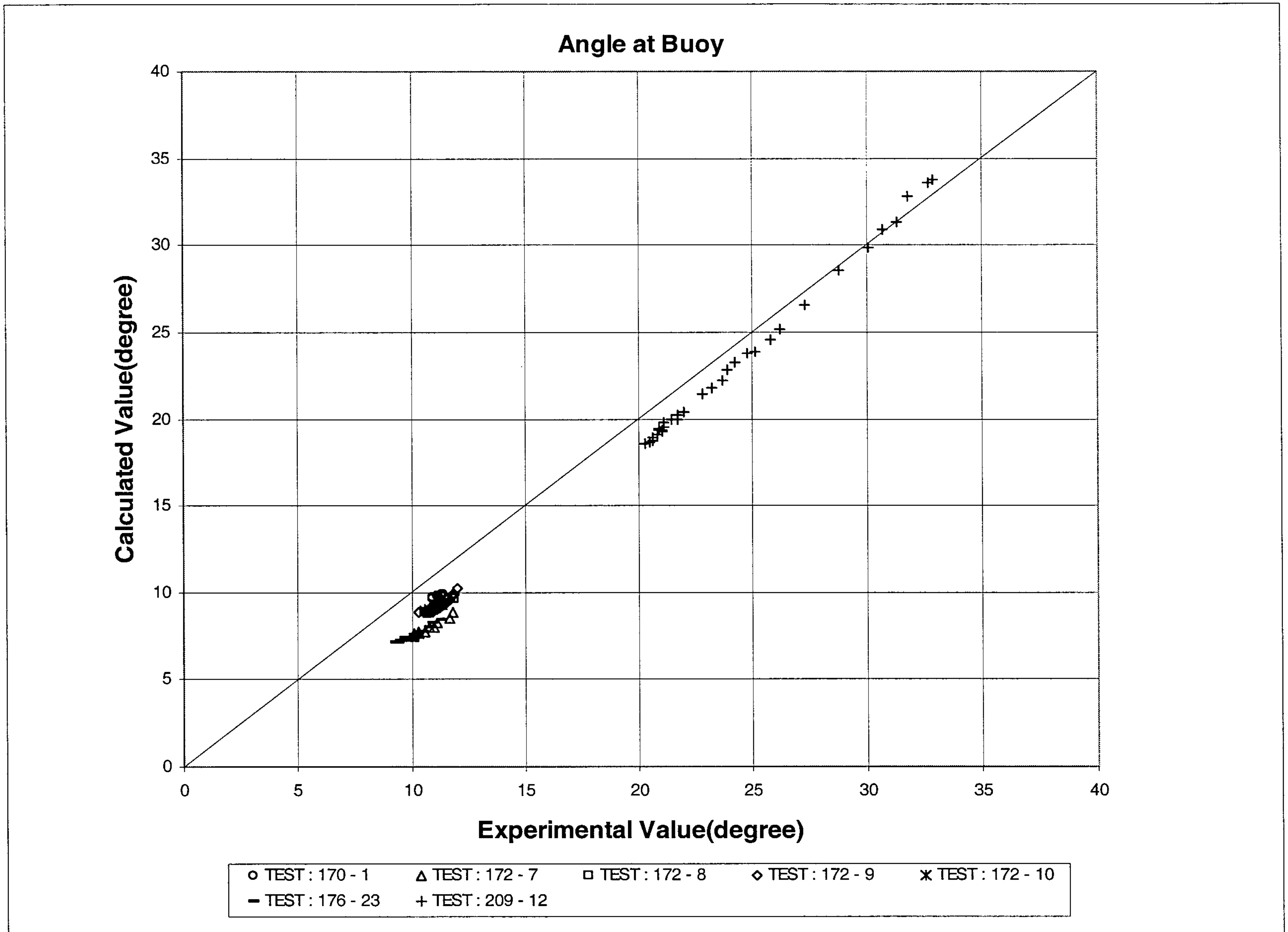


Figure – 49 Comparison of Angle at Buoy

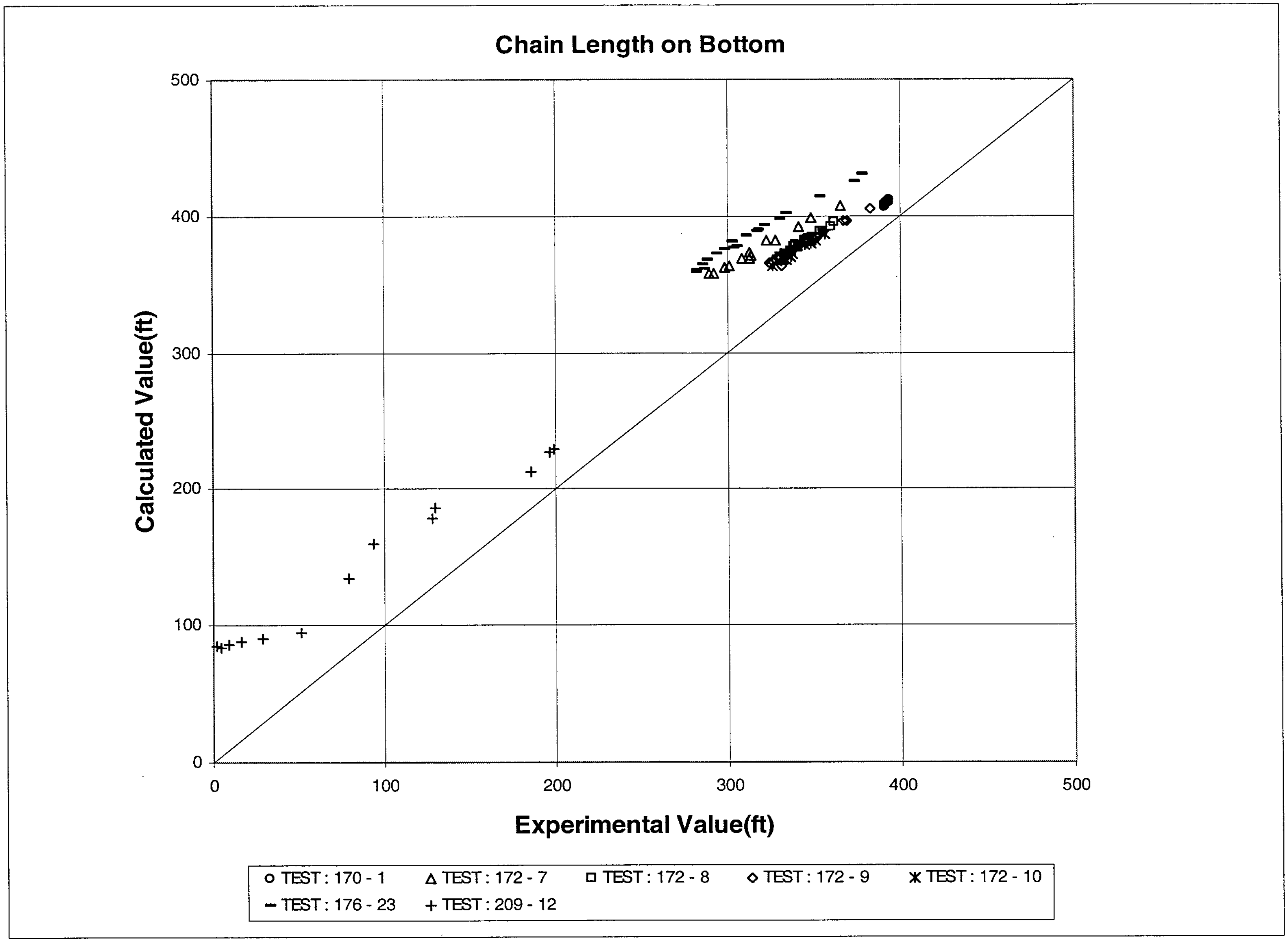


Figure – 50 Comparison of Chain Length On Bottom

APPENDIX

FACTORS OF SURFACE FRICTION (Indian Island)

Number	Anchor Crown	Water	Deck Hori.	Anchor	Deck H. For. -	Total Bottom	Surface Friction	Remark
	Depth #11	Depth #14	Force #8	Force #3	Anc. For.	Weight #15	Factor (#8-#3)/#15	
170-1	89.7	86.4	13400	2800	10600	21843.9	0.485	silt
172-7	80.6	78.8	17300	2500	14800	20937	0.707	silt
172-8	91.2	90.8	20300	3300	17000	20646.2	0.823	silt
172-9	93.2	92.2	17500	200	17300	25801.9	0.670	silt
172-10	92	92	23100	800	22300	25004.7	0.892	silt
174-13	87.2	86.9	19600	No data	***	27198.4	***	silt
174-14	88.9	88.9	22000	No data	***	26946.6	***	silt
176-23	80.8	81.9	28700	600	28100	22979.8	1.223	silt
176-25	93	89.3	41700	No data	***	23461.4	***	silt
208-5	88	89	13800	7600	6200	20250.7	0.306	silty clay
209-12	85.8	88	13200	100	13100	28303.1	0.463	silty clay

numbers are from the report of Indian island tests.

TEST : 170 - 1

Anchor
Type : STATO, 1000 lbs, 16 in Stabilizers, 50 degree Movable Flukes

Anchor Weight : 1070 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
a1	89.7	3.3	13400	No Result	2800	######	No Result	16.4	######	No Result	447.1	######
a2	89.8	3.4	12500	No Result	2200	######	No Result	17.1	######	No Result	449.3	######
a3	89.8	3.4	14000	No Result	2400	######	No Result	16.4	######	No Result	443.8	######
a4	89.9	3.5	15700	No Result	2600	######	No Result	15.5	######	No Result	439.1	######
a5	90.3	3.9	18700	No Result	3400	######	No Result	14.1	######	No Result	432.1	######
a6	91	4.6	18700	No Result	4400	######	No Result	14.2	######	No Result	431.9	######
a7	91.5	5.1	19200	No Result	4800	######	No Result	14.1	######	No Result	429.4	######
a8	92.1	5.7	21400	No Result	5600	######	No Result	13.5	######	No Result	423.3	######
a9	92.5	6.1	24000	No Result	6800	######	No Result	13	######	No Result	415.6	######
a10	92.9	6.5	24500	No Result	7400	######	No Result	12.9	######	No Result	413.5	######
a11	93	6.6	25600	No Result	8600	######	No Result	12.5	######	No Result	412.7	######
a12	93.7	7.3	27900	No Result	10000	######	No Result	12.3	######	No Result	405	######
a13	94.4	8	28900	No Result	10400	######	No Result	12.1	######	No Result	402.4	######
a14	95.5	9.1	29900	No Result	10800	######	No Result	11.9	######	No Result	400.2	######
a15	No Data	No Data	30900	No Result	11200	######	No Result	11.7	######	No Result	397.9	######
a16	96.3	9.9	31500	No Result	11400	######	No Result	11.5	######	No Result	397.6	######
a17	96.3	9.9	32700	6861.6	11800	0.4185	9.92	11.4	0.1298	411.44	393.8	-0.0448
a18	96	9.6	31400	No Result	11600	######	No Result	11.4	######	No Result	399.5	######
a19	96.2	9.8	33000	7193.92	12400	0.4198	9.89	11.4	0.1325	411.03	393.3	-0.0451
a20	96.3	9.9	32900	7076.99	12400	0.4293	9.9	11.3	0.1239	411	394	-0.0431
a21	96.7	10.3	33300	7424.35	12400	0.4013	9.86	11.3	0.1274	410.38	393.1	-0.044
a22	96.7	10.3	34000	8191.43	13000	0.3699	9.78	11.3	0.1345	408.86	390.8	-0.0462
a23	96.8	10.4	33900	8054.44	13200	0.3898	9.79	11.2	0.1259	409.24	392.2	-0.0434
a24	96.9	10.5	33800	7932.13	13000	0.3898	9.8	11.1	0.1171	409.29	393.6	-0.0399
a25	96.8	10.4	34800	9048.38	14000	0.3537	9.7	10.9	0.1101	407.38	392.2	-0.0387
a26	97.4	11	35200	9353.82	14600	0.3593	9.67	10.9	0.1128	406.42	390.8	-0.04

Water Depth(ft) : 86.4

Note : units are feet, lbs and degree.

TEST : 172 - 7

Anchor

Type : STOCKLESS, 9000 lbs, Stabilizers, 48 degree Fixed Flukes

Anchor Weight : 11370 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
b1	80.6	1.8	17300	No Result	2500	######	No Result	15.8	######	No Result	427.7	######
b2	81.3	2.5	22600	No Result	No Data	######	No Result	14.7	######	No Result	407.9	######
b3	81.8	3	23500	No Result	9100	######	No Result	14.1	######	No Result	407.6	######
b4	81.9	3.1	24400	No Result	10100	######	No Result	14	######	No Result	404.4	######
b5	82.3	3.5	24900	No Result	No Data	######	No Result	13.8	######	No Result	404.1	######
b6	83.1	4.3	28000	No Result	No Data	######	No Result	13.1	######	No Result	395.9	######
b7	83.1	4.3	31400	No Result	No Data	######	No Result	12.8	######	No Result	383.9	######
b8	84.2	5.4	35500	No Result	No Data	######	No Result	12.2	######	No Result	372.5	######
b9	84.8	6	38300	9320.16	22000	0.5764	8.84	11.8	0.2508	407.31	365.6	-0.1141
b10	85.4	6.6	43100	14764.93	No Data	######	8.49	11.7	0.2744	398.69	348.7	-0.1434
b11	86.4	7.6	25100	NO Result	26800	######	NO Result	11.4	######	NO Result	425.3	######
b12	87.2	8.4	46900	18723.56	No Data	######	8.26	11.1	0.2559	391.73	341.6	-0.1468
b13	87.9	9.1	52200	24567.57	No Data	######	7.99	11	0.2736	382.4	322.7	-0.185
b14	88.8	10	52100	24155.62	31600	0.2356	7.99	10.8	0.2602	382.61	327.9	-0.1668
b15	91.6	12.8	57300	29078.14	NO Data	######	7.76	10.6	0.2679	373.56	312.3	-0.1962
b16	92.5	13.7	58500	30106.71	32600	0.0765	7.72	10.3	0.2505	371.42	313.8	-0.1836
b17	93.1	14.3	60200	31783.76	No Data	######	7.65	10.3	0.2573	368.54	308.2	-0.1958
b18	94	15.2	59800	30985.16	33100	0.0639	7.66	10.1	0.2416	369.28	312.7	-0.1809
b19	93.9	15.1	63400	35048.41	36600	0.0424	7.54	10.1	0.2535	363.1	300.7	-0.2075
b20	94	15.2	64100	35797.4	37600	0.0479	7.51	10.1	0.2564	361.82	298.2	-0.2133
b21	94.4	15.6	63900	35405.11	No Data	######	7.52	10.1	0.2554	362.28	298.3	-0.2145
b22	95	16.2	66300	37830.64	35900	-0.054	7.44	10	0.256	358.02	291.8	-0.2269
b23	95	16.2	66400	37951.27	No Data	######	7.44	10.1	0.2634	357.75	289.4	-0.2362

Water Depth(ft) : 78.8

Note : units are feet, lbs and degree.

TEST : 172 - 8

Anchor
Type : STOCKLESS, 9000 lbs, Stabilizers, 48 degree Movable Flukes

Anchor Weight : 11370 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
c1	91.2	0.4	20300	No Result	3300	######	No Result	14.4	######	No Result	421.9	######
c2	99	8.2	27700	No Result	9600	######	No Result	12.8	######	No Result	399.7	######
c3	99.7	8.9	31000	No Result	11400	######	No Result	12.8	######	No Result	385	######
c4	99.2	8.4	32900	No Result	12600	######	No Result	12.6	######	No Result	379.2	######
c5	100	9.2	34800	No Result	14700	######	No Result	12.2	######	No Result	375.1	######
c6	100.5	9.7	36900	No Result	15900	######	No Result	12	######	No Result	368.7	######
c7	100.3	9.5	39000	8241.63	17700	0.5344	9.64	11.9	0.1899	394.89	361.8	-0.0915
c8	101.5	10.7	40400	9620.53	18700	0.4855	9.53	11.6	0.1784	392.22	360	-0.0895
c9	101.1	10.3	42200	11829.38	20500	0.423	9.4	11.5	0.1826	388.43	354.5	-0.0957
c10	101.8	11	42300	11772.07	21000	0.4394	9.39	11.4	0.1763	388.24	355.5	-0.0921
c11	102	11.2	43900	13586.67	22500	0.3961	9.28	11.4	0.186	384.79	349.5	-0.101
c12	101.9	11.1	45000	14876.09	23500	0.367	9.21	11.3	0.185	382.72	346.9	-0.1033
c13	102.6	11.8	45200	14936.88	24000	0.3776	9.2	11.3	0.1858	382.23	345	-0.1079
c14	102.1	11.3	45600	15545.17	24500	0.3655	9.18	11.2	0.1804	381.37	345.7	-0.1032
c15	102.9	12.1	45300	14969.5	24000	0.3763	9.2	11.1	0.1712	381.94	348.1	-0.0972
c16	102.4	11.6	47000	17092.38	25800	0.3375	9.09	11.2	0.1884	378.45	339.4	-0.1151
c17	103	12.2	46000	15724.2	24800	0.366	9.15	11.1	0.1757	380.79	345.4	-0.1025
c18	103.5	12.7	47700	17556.14	26800	0.3449	9.05	11.1	0.1847	377.22	339	-0.1127
c19	103.3	12.5	47700	17619.27	26500	0.3351	9.05	11	0.1773	377.17	341.6	-0.1041
c20	103.4	12.6	48900	18951.65	27500	0.3108	8.98	11	0.1836	374.89	336.9	-0.1128
c21	103.8	13	50200	20336.47	28000	0.2737	8.92	10.9	0.1817	372.14	333.1	-0.1172
c22	103.7	12.9	49500	19549.76	27300	0.2839	8.95	10.8	0.1713	373.57	337.4	-0.1072
c23	104	13.2	51400	21641.3	29100	0.2563	8.85	10.8	0.1806	369.68	330.2	-0.1196
c24	103.8	13	51800	22169.91	29600	0.251	8.83	10.7	0.1748	368.92	330.7	-0.1156
c25	104.2	13.4	52400	22707.85	30300	0.2506	8.8	10.7	0.1776	367.9	329.1	-0.1179
c26	104.1	13.3	52000	22284.34	30300	0.2645	8.82	10.6	0.1679	368.61	330.8	-0.1143

Water Depth(ft) : 90.8

Note : units are feet, lbs and degree.

TEST : 172 - 9

Anchor Type : STOCKLESS, 5000 lbs, Stabilizers, 48 degree Fixed Flukes

Anchor Weight : 5950 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
d1	93.2	1	17500	No Result	200	######	No Result	15.6	######	No Result	428.7	######
d2	93.3	1.1	17400	No Result	200	######	No Result	15.7	######	No Result	428.6	######
d3	93.4	1.2	18200	No Result	600	######	No Result	15.3	######	No Result	426.8	######
d4	93.5	1.3	18400	No Result	600	######	No Result	15.1	######	No Result	426.6	######
d5	93.5	1.3	19500	No Result	800	######	No Result	14.7	######	No Result	423.9	######
d6	93.7	1.5	20400	No Result	1000	######	No Result	14.5	######	No Result	420.5	######
d7	93.7	1.5	20500	No Result	1200	######	No Result	14.2	######	No Result	422.3	######
d8	94	1.8	21700	No Result	1400	######	No Result	14.1	######	No Result	417.2	######
d9	94.1	1.9	22100	No Result	1600	######	No Result	14	######	No Result	416.2	######
d10	94.7	2.5	23700	No Result	2200	######	No Result	13.6	######	No Result	411.5	######
d11	94.9	2.7	25600	No Result	2800	######	No Result	13.5	######	No Result	403.8	######
d12	95.4	3.2	26000	No Result	3000	######	No Result	13.2	######	No Result	404.3	######
d13	95.7	3.5	27600	No Result	4000	######	No Result	13	######	No Result	398.6	######
d14	96.1	3.9	29200	No Result	5200	######	No Result	12.9	######	No Result	392.9	######
d15	96	3.8	31300	No Result	7000	######	No Result	12.5	######	No Result	388.1	######
d16	97	4.8	33700	5621.4	8400	0.3308	10.23	12	0.1475	404.86	382.6	-0.0582
d17	97.1	4.9	37600	10250.89	11200	0.0847	9.85	11.9	0.1723	396.75	367.8	-0.0787
d18	97.4	5.2	37500	10094.53	11400	0.1145	9.86	11.8	0.1644	396.98	369.6	-0.0741
d19	97.9	5.7	41200	14396.19	13400	-0.074	9.57	11.7	0.1821	389.13	356.2	-0.0924
d20	98.2	6	43300	16795.35	14600	-0.15	9.42	11.4	0.1737	384.83	351.9	-0.0936
d21	98.7	6.5	44100	17631.31	14800	-0.191	9.36	11.3	0.1717	383.24	350.2	-0.0943
d22	99	6.8	46500	20379.93	16400	-0.243	9.22	11.3	0.1841	378.03	340.7	-0.1096
d23	99.2	7	47200	21134.22	16600	-0.273	9.18	11.2	0.1804	376.65	339.9	-0.1081
d24	99.6	7.4	49400	23592.93	17800	-0.325	9.05	11.1	0.1847	372.24	332.9	-0.1182
d25	99.9	7.7	49800	23984.78	18000	-0.332	9.03	11	0.1791	371.31	332.5	-0.1167
d26	100.2	8	49700	23756.45	18400	-0.291	9.03	10.9	0.1716	371.73	335	-0.1096
d27	103.6	11.4	51000	24203.33	18800	-0.287	8.97	10.9	0.1771	368.87	329.9	-0.1181
d28	103.5	11.3	52000	25360.93	19800	-0.281	8.91	10.9	0.1826	367.05	326.3	-0.1249
d29	101.6	9.4	52600	26674.6	20400	-0.308	8.89	10.9	0.1844	365.85	324.3	-0.1281
d30	102.3	10.1	52900	26807.34	20400	-0.314	8.88	10.8	0.1778	365.03	325.1	-0.1228
d31	102.8	10.6	53500	27321.5	20600	-0.326	8.85	10.3	0.1408	363.76	331.8	-0.0963

Water Depth(ft) : 92.2

Note : units are feet, lbs and degree.

TEST : 172 - 10

Anchor Type : STOCKLESS, 5000 lbs, Stabilizers, 48 degree Fixed Flukes

Anchor Weight : 5950 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
e1	92	0	23100	No Result	800	######	No Result	13.8	######	No Result	412.8	######
e2	92.6	0.6	23400	No Result	1200	######	No Result	13.8	######	No Result	411.2	######
e3	93.1	1.1	23600	No Result	1600	######	No Result	13.6	######	No Result	411.5	######
e4	93.4	1.4	24900	No Result	2400	######	No Result	13.5	######	No Result	406.8	######
e5	94.2	2.2	27100	No Result	3600	######	No Result	13.1	######	No Result	400.2	######
e6	94.4	2.4	27700	No Result	4200	######	No Result	12.8	######	No Result	400.7	######
e7	95.1	3.1	30300	No Result	6200	######	No Result	12.7	######	No Result	389.8	######
e8	96.9	4.9	32300	No Result	7400	######	No Result	12.4	######	No Result	384.4	######
e9	98.3	6.3	35500	No Result	9200	######	No Result	11.9	######	No Result	376.1	######
e10	98.6	6.6	39100	No Result	11800	######	No Result	11.5	######	No Result	366.7	######
e11	98.7	6.7	39900	No Result	12600	######	No Result	11.6	######	No Result	362.6	######
e12	99.1	7.1	42200	11395.32	14000	0.186	9.48	11.4	0.1684	387.09	356.6	-0.0855
e13	99.5	7.5	44700	14317.77	15600	0.0822	9.31	11.3	0.1761	382.21	347.9	-0.0986
e14	99.8	7.8	44600	14159.74	15400	0.0805	9.32	11.1	0.1604	382.13	351.1	-0.0884
e15	101.1	9.1	46300	15886.21	16800	0.0544	9.22	11.1	0.1694	378.71	344.7	-0.0987
e16	101.3	9.3	45500	14898.01	16000	0.0689	9.26	11	0.1582	380.41	349	-0.09
e17	101.9	9.9	48600	18420.16	18000	-0.023	9.08	11	0.1745	374.03	337	-0.1099
e18	102.4	10.4	49900	19833.64	19000	-0.044	9.01	10.9	0.1734	371.29	335	-0.1083
e19	102.2	10.2	49400	19297.76	18800	-0.026	9.04	10.8	0.163	372.34	338.1	-0.1013
e20	102.1	10.1	50800	20951.62	19600	-0.069	8.96	10.8	0.1704	369.61	332.4	-0.1119
e21	102.4	10.4	50600	20654.32	19000	-0.087	8.98	10.6	0.1528	369.77	336.5	-0.0989
e22	102.5	10.5	52300	22607.55	20200	-0.119	8.89	10.7	0.1692	366.5	329.2	-0.1133
e23	103	11	51700	21751.81	19800	-0.099	8.92	10.6	0.1585	367.79	333.8	-0.1018
e24	104.4	12.4	53600	23542.43	19600	-0.201	8.83	10.7	0.1748	363.86	326.5	-0.1144
e25	103.2	11.2	51700	21691.03	17800	-0.219	8.92	10.6	0.1585	367.8	332.8	-0.1052

Water Depth(ft) : 92

Note : units are feet, lbs and degree.

TEST : 176 - 23

Anchor Type : STATO, 3000 lbs, with 18 in Stabilizer Extensions

Anchor Weight : 3500 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
i1	80.8	-1.1	28700	No Result	600	######	No Result	13.1	######	No Result	437.8	######
i2	81.1	-0.8	28000	No Result	1000	######	No Result	13.1	######	No Result	441	######
i3	81	-0.9	29300	No Result	2400	######	No Result	13.1	######	No Result	435.4	######
i4	81.9	0	30900	No Result	3400	######	No Result	12.9	######	No Result	429.8	######
i5	81.9	0	33200	No Result	5000	######	No Result	12.7	######	No Result	421.6	######
i6	83	1.1	35000	No Result	5800	######	No Result	12.3	######	No Result	418.5	######
i7	83.4	1.5	38100	No Result	7200	######	No Result	12.1	######	No Result	408.8	######
i8	84.8	2.9	38900	No Result	8400	######	No Result	11.9	######	No Result	408.1	######
i9	85.6	3.7	41700	No Result	10000	######	No Result	11.6	######	No Result	399.4	######
i10	86.9	5	48300	8768.04	14200	0.3825	8.41	11.3	0.2558	430.23	378.5	-0.1367
i11	88.4	6.5	51100	12172.27	16200	0.2486	8.27	10.9	0.2413	424.84	373.6	-0.1372
i12	89.3	7.4	56700	18981.51	19600	0.0316	8.02	10.8	0.2574	414.64	354.1	-0.171
i13	90.4	8.5	63800	27440.56	24000	-0.143	7.75	10.5	0.2619	401.99	333.8	-0.2043
i14	91.6	9.7	68600	32949.95	25600	-0.287	7.6	10.3	0.2621	393.43	321.4	-0.2241
i15	92.2	10.3	66500	30211.8	25400	-0.189	7.66	10.3	0.2563	397.32	330.4	-0.2025
i16	93	11.1	70900	35271.54	26600	-0.326	7.54	10.2	0.2608	389.33	317.6	-0.2259
i17	93.4	11.5	72900	37510.1	28800	-0.302	7.48	10.1	0.2594	385.86	310.7	-0.2419
i18	93.5	11.6	71500	35805.54	27600	-0.297	7.52	10.1	0.2554	388.43	317.5	-0.2234
i19	94.3	12.4	75600	40406.85	30600	-0.32	7.41	10.1	0.2663	381.19	303	-0.2581
i20	94.6	12.7	78400	43644	31200	-0.399	7.34	9.9	0.2586	376.05	298.6	-0.2594
i21	95	13.1	78200	43193.93	31200	-0.384	7.34	9.7	0.2433	376.83	303.6	-0.2412
i22	95.2	13.3	80600	45953.98	30000	-0.532	7.28	9.8	0.2571	372.64	293.6	-0.2692
i23	95.5	13.6	77800	42548.88	30200	-0.409	7.35	9.7	0.2423	377.38	305.4	-0.2357
i24	95.8	13.9	83200	48804.63	32800	-0.488	7.23	9.7	0.2546	367.94	288	-0.2776
i25	96.5	14.6	85400	51080.73	34400	-0.485	7.18	9.5	0.2442	364.33	285.2	-0.2775
i26	94.3	12.4	No Data	No Result	35000	######	No Result	9.4	######	No Result	No data	X
i27	97.1	15.2	87400	53158.86	38200	-0.392	7.14	9.4	0.2404	360.66	281.7	-0.2803
i28	97.6	15.7	87200	52664.76	37400	-0.408	7.14	9.3	0.2323	361.48	286.7	-0.2608
i29	97.1	15.2	88200	54118.02	37000	-0.463	7.12	9.3	0.2344	359.29	282.4	-0.2723

Water Depth(ft) : 81.9

Note : units are feet, lbs and degree.

TEST : 208 - 5

Anchor
Type : Two Fluke Balanced W/ Ballguide

Anchor Weight : 9800 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
/1	88	-1	13800	No Result	7600	######	No Result	46.9	######	No Result	245.1	######
/2	88	-1	14400	No Result	8300	######	No Result	46.2	######	No Result	241.5	######
/3	88.2	-0.8	14900	No Result	8700	######	No Result	45.6	######	No Result	238.6	######
/4	88.2	-0.8	15300	No Result	9100	######	No Result	45.2	######	No Result	236.1	######
/5	90.1	1.1	14600	No Result	9300	######	No Result	46	######	No Result	240.2	######
/6	90.2	1.2	14800	No Result	9900	######	No Result	45.8	######	No Result	238.9	######
/7	90.4	1.4	15300	No Result	10400	######	No Result	45.3	######	No Result	235.8	######
/8	90.6	1.6	15600	No Result	11600	######	No Result	44.9	######	No Result	234.3	######
/9	90.9	1.9	15800	No Result	11700	######	No Result	44.7	######	No Result	233.1	######
/10	91.5	2.5	16100	No Result	13100	######	No Result	44.3	######	No Result	231.7	######
/11	91.7	2.7	15800	No Result	12500	######	No Result	44.7	######	No Result	233.1	######
/12	91.9	2.9	16900	No Result	14300	######	No Result	43.5	######	No Result	227.3	######
/13	92.3	3.3	17800	No Result	15000	######	No Result	42.7	######	No Result	222	######
/14	92.8	3.8	18200	No Result	14700	######	No Result	42.3	######	No Result	219.9	######
/15	93	4	18900	No Result	16300	######	No Result	41.7	######	No Result	216.4	######
/16	93.2	4.2	19200	No Result	16300	######	No Result	41.4	######	No Result	214.7	######
/17	93.7	4.7	20300	No Result	16900	######	No Result	40.5	######	No Result	209.4	######
/18	93.9	4.9	21700	No Result	18200	######	No Result	39.5	######	No Result	202	######
/19	94.1	5.1	21800	No Result	17300	######	No Result	39.4	######	No Result	201.4	######
/20	94.2	5.2	23400	No Result	18700	######	No Result	38.3	######	No Result	193.7	######
/21	94.2	5.2	23500	No Result	18200	######	No Result	38.2	######	No Result	193.2	######
/22	94.7	5.7	23400	No Result	19100	######	No Result	38.3	######	No Result	193.8	######
/23	94.8	5.8	23700	No Result	20000	######	No Result	38.1	######	No Result	191.9	######
/24	94.9	5.9	24000	No Result	20100	######	No Result	37.9	######	No Result	190.5	######
/25	95.1	6.1	24300	No Result	19900	######	No Result	37.7	######	No Result	189.1	######

Water Depth(ft) : 89

Note : units are feet, lbs and degree.

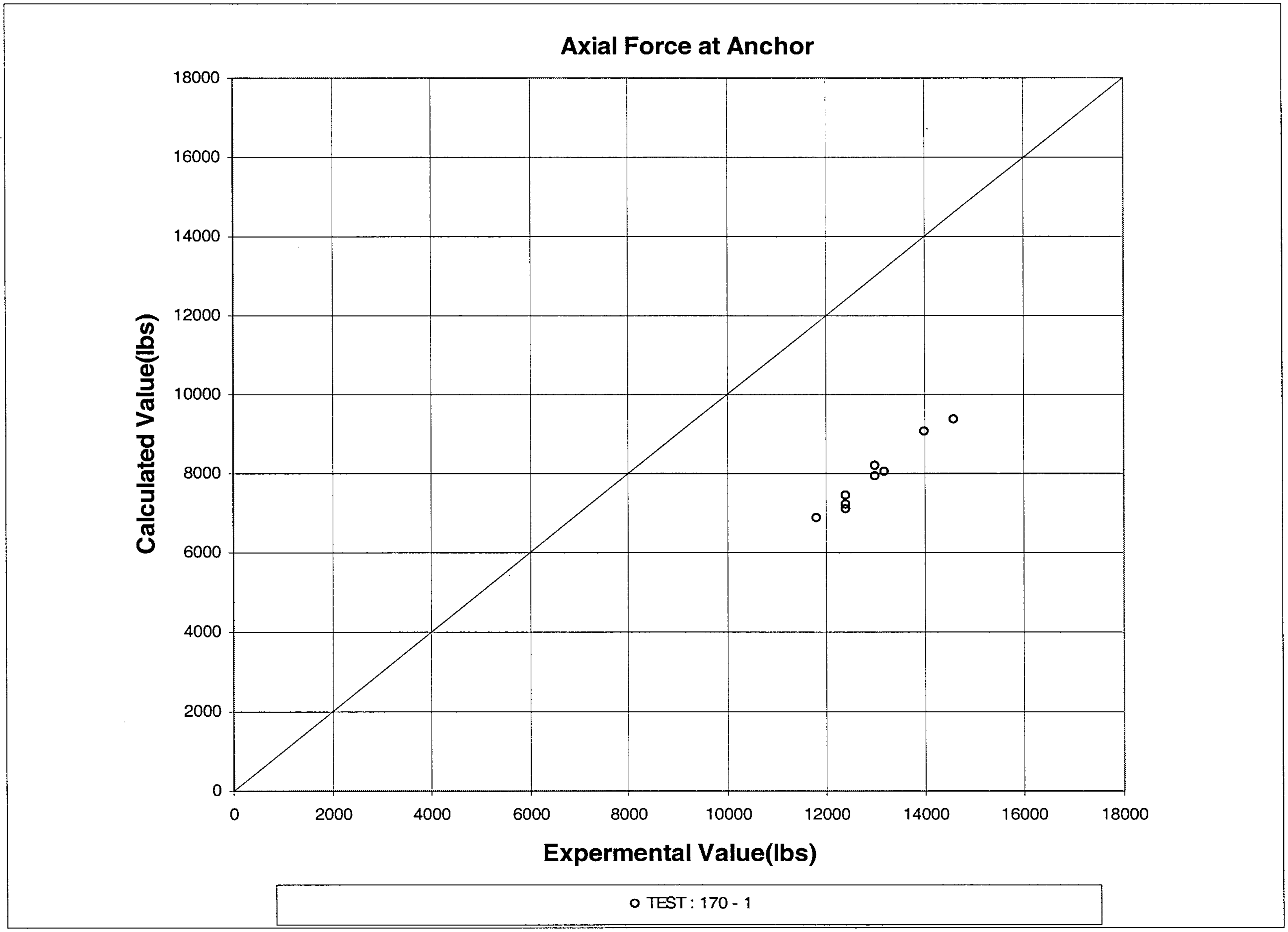
TEST : 209 - 12 Anchor Type : STEVFIX Anchor Weight : 11000 lbs

No.	Anchor Depth	Anchor Depth from seafloor	Horizontal Tension	Axial Force at Anchor (Program)	Axial Force at Anchor (Field Test)	Error	Angle at Buoy (Program)	Angle at Buoy (Field Test)	Error	Chain Length on Bottom (Program)	Chain Length on Bottom (Field Test)	Error
m1	85.8	-2.2	13200	No Result	100	######	No Result	47.5	######	No Result	340.3	######
m2	86.1	-1.9	13700	No Result	3400	######	No Result	46.9	######	No Result	337.2	######
m3	86.1	-1.9	13700	No Result	3500	######	No Result	46.9	######	No Result	337.2	######
m4	86.2	-1.8	14300	No Result	3900	######	No Result	46.2	######	No Result	333.5	######
m5	86.4	-1.6	15400	No Result	5000	######	No Result	44.9	######	No Result	327.3	######
m6	86.6	-1.4	15700	No Result	6000	######	No Result	44.6	######	No Result	325.5	######
m7	87.5	-0.5	16100	No Result	8400	######	No Result	44.2	######	No Result	323.1	######
m8	87.6	-0.4	16500	No Result	8300	######	No Result	43.8	######	No Result	320.8	######
m9	87.7	-0.3	18000	No Result	9400	######	No Result	42.3	######	No Result	312.8	######
m10	87.9	-0.1	21300	No Result	11400	######	No Result	39.6	######	No Result	295.6	######
m11	87.9	-0.1	21800	No Result	11500	######	No Result	39.2	######	No Result	292.3	######
m12	88.2	0.2	22700	No Result	13400	######	No Result	38.6	######	No Result	288.9	######
m13	88.5	0.5	24000	No Result	13700	######	No Result	37.2	######	No Result	286.2	######
m14	88.5	0.5	24700	No Result	13700	######	No Result	37.2	######	No Result	279.9	######
m15	88.5	0.5	26700	No Result	14900	######	No Result	36	######	No Result	270.5	######
m16	89.4	1.4	27700	No Result	17900	######	No Result	35.3	######	No Result	263.4	######
m17	89.9	1.9	28200	No Result	19000	######	No Result	35.2	######	No Result	256.5	######
m18	90.5	2.5	28700	No Result	21300	######	No Result	34.8	######	No Result	252.8	######
m19	90.9	2.9	29700	No Result	22700	######	No Result	34.5	######	No Result	240.5	######
m20	91.1	3.1	30600	No Result	23700	######	No Result	34.3	######	No Result	226.4	######
m21	92.4	4.4	33600	20722.86	27200	0.2381	33.71	32.9	-0.025	228.73	199.3	-0.1477
m22	92.2	4.2	34000	21260.96	26700	0.2037	33.54	32.7	-0.026	226.86	196	-0.1574
m23	92.8	4.8	35700	23561.56	30700	0.2325	32.78	31.8	-0.031	212.69	185.7	-0.1453
m24	93.2	5.2	39300	28370.48	31500	0.0993	31.3	31.3	0	186.41	130	-0.4339
m25	93.4	5.4	40400	29820.12	33300	0.1045	30.88	30.7	-0.006	178.77	128.1	-0.3956
m26	93.8	5.8	43200	33443.35	35100	0.0472	29.87	30.1	0.0076	159.8	93.4	-0.7109
m27	94.3	6.3	47300	38602.46	38400	-0.005	28.53	28.8	0.0094	134.85	78.9	-0.7091
m28	95.5	75	54200	46922.82	44600	-0.052	26.59	27.3	0.026	94.26	51.2	-0.841
m29	96.5	76	60100	52171.6	48300	-0.08	25.19	26.2	0.0385	89.93	28.9	-2.1118
m30	97	76.5	63000	54773.54	51800	-0.057	24.55	25.8	0.0484	87.79	16.2	-4.4191
m31	95.9	75.4	67000	59624.21	55100	-0.082	23.82	25.1	0.051	84.22	4.2	-19.052

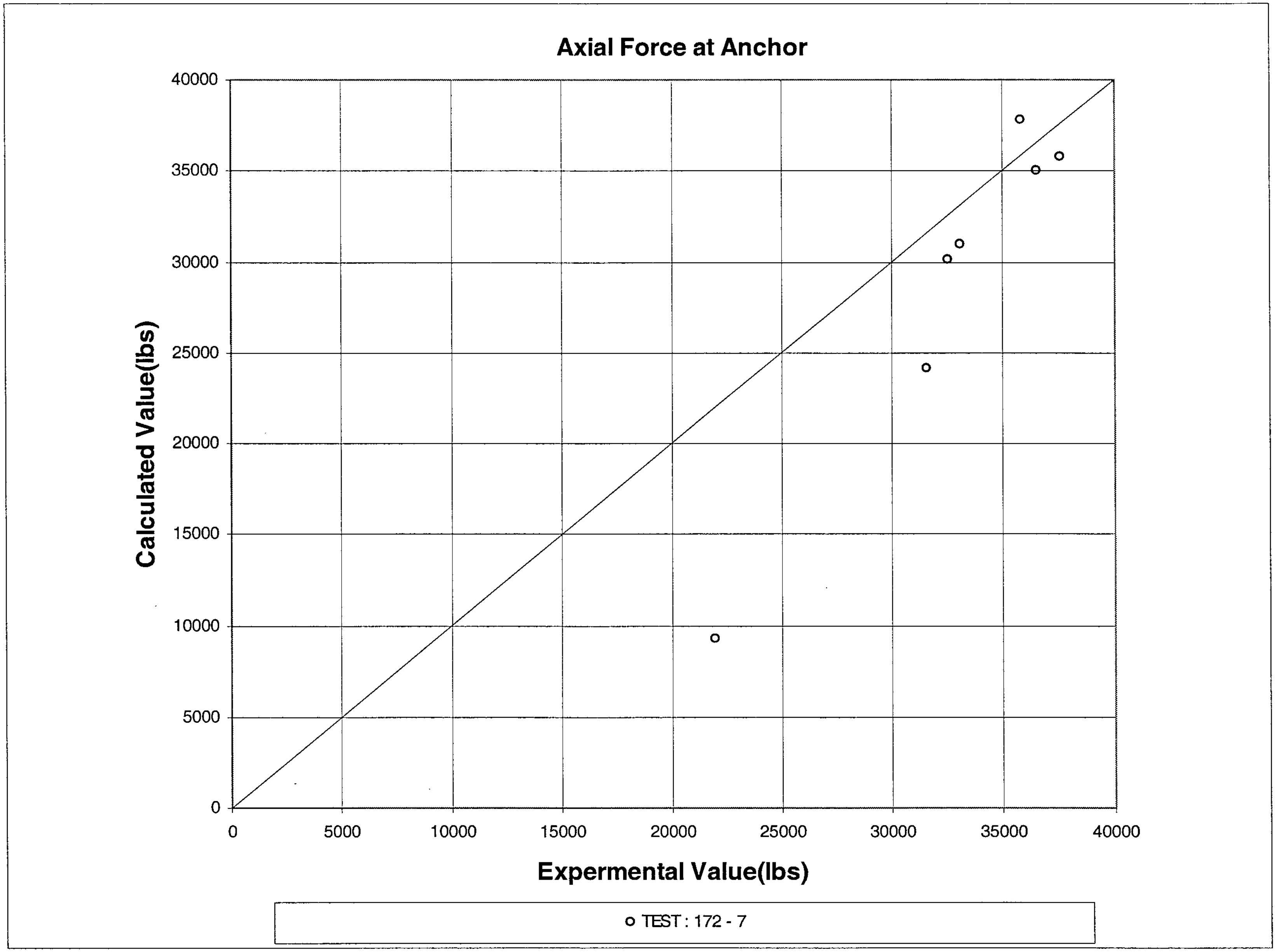
m32	96.7	76.2	67200	59210.27	54600	-0.084	23.78	24.8	0.0411	85.44	8.6	-8.9349
m33	97	76.5	70200	62001.41	56300	-0.101	23.27	24.2	0.0384	84.4	1.6	-51.75
m34	97.6	9.6	73200	64525.25	57600	-0.12	22.8	23.9	0.046	84.33	No Data	X
m35	98	10	76900	67996.88	61500	-0.106	22.23	23.7	0.062	82.3	No Data	X
m36	98.7	10.7	80000	70518.16	64500	-0.093	21.82	23.2	0.0595	82.56	No Data	X
m37	99.3	11.3	83000	73031.49	64500	-0.132	21.45	22.8	0.0592	82.46	No Data	X
m38	100.5	12.5	92700	81702.87	75400	-0.084	20.41	22	0.0723	82	No Data	X
m39	101.2	13.2	94800	83135.63	76200	-0.091	20.22	21.7	0.0682	83.18	No Data	X
m40	101.5	13.5	97600	85632.73	78000	-0.098	19.97	21.7	0.0797	83.44	No Data	X
m41	102.6	14.6	98200	85215.95	79300	-0.075	19.93	21.4	0.0687	85.14	No Data	X
m42	103.6	15.6	99800	85849.39	80000	-0.073	19.81	21.1	0.0611	86.71	No Data	X
m43	104.5	16.5	103600	89164.89	87900	-0.014	19.48	21.1	0.0768	87.47	No Data	X
m44	105.8	17.8	104600	88896.83	93100	0.0451	19.43	20.9	0.0703	89.34	No Data	X
m45	106.2	18.2	105600	89551.09	93500	0.0422	19.36	20.9	0.0737	89.32	No Data	X
m46	106.8	18.8	106000	88930.86	94300	0.0569	19.37	21	0.0776	90.49	No Data	X
m47	106.5	18.5	107400	90187.05	95200	0.0527	19.29	21	0.0814	90.15	No Data	X
m48	107.8	19.8	109900	91818.61	98200	0.065	19.1	20.8	0.0817	92.36	No Data	X
m49	108.5	20.5	113200	94159.23	101700	0.0741	18.91	20.6	0.082	92.29	No Data	X
m50	108.8	20.8	115600	96684.34	101900	0.0512	18.72	20.6	0.0913	93.56	No Data	X
m51	108.7	20.7	117100	97850.05	102900	0.0491	18.66	20.5	0.0898	92.56	No Data	X
m52	108.6	20.6	118100	98903.45	103600	0.0453	18.59	20.3	0.0842	92.6	No Data	X
m53	109.9	21.9	118700	98601.7	105300	0.0636	18.56	20.3	0.0857	94.21	No Data	X

Water Depth(ft) : 88

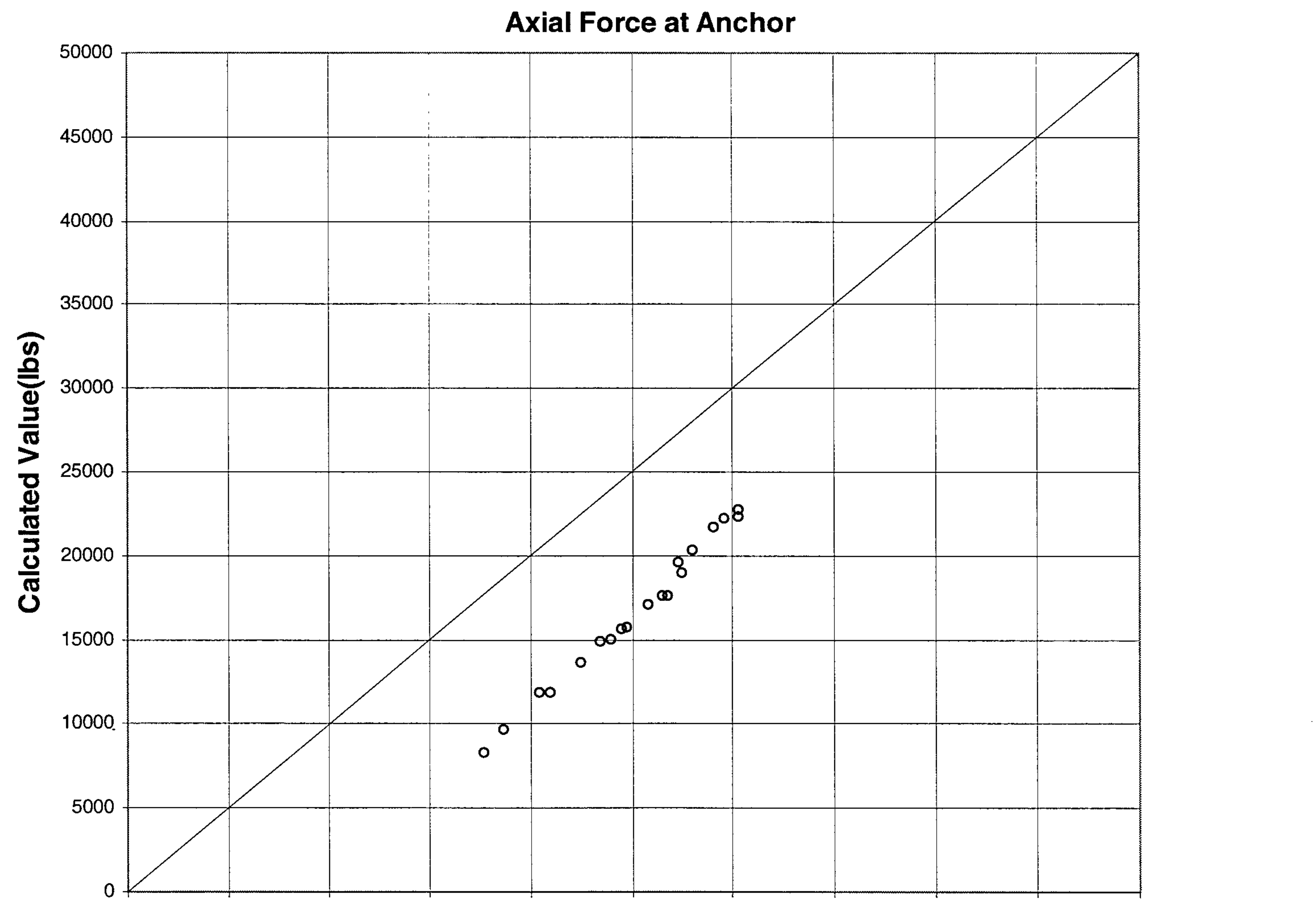
Note : units are feet, lbs and degree.



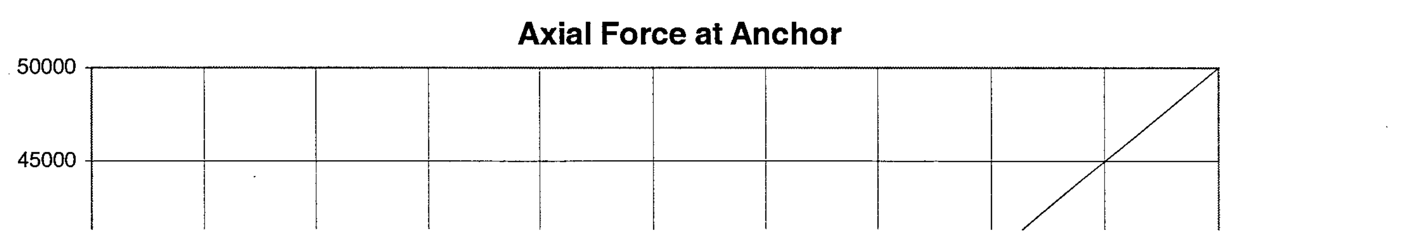
Axial Force at Anchor
18000
16000
14000
12000
10000
8000
6000
4000
2000
0
Calculated Value(lbs)
0
2000
4000
6000
8000
10000
12000
14000
16000
18000
Expermental Value(lbs)
TEST : 170 - 1



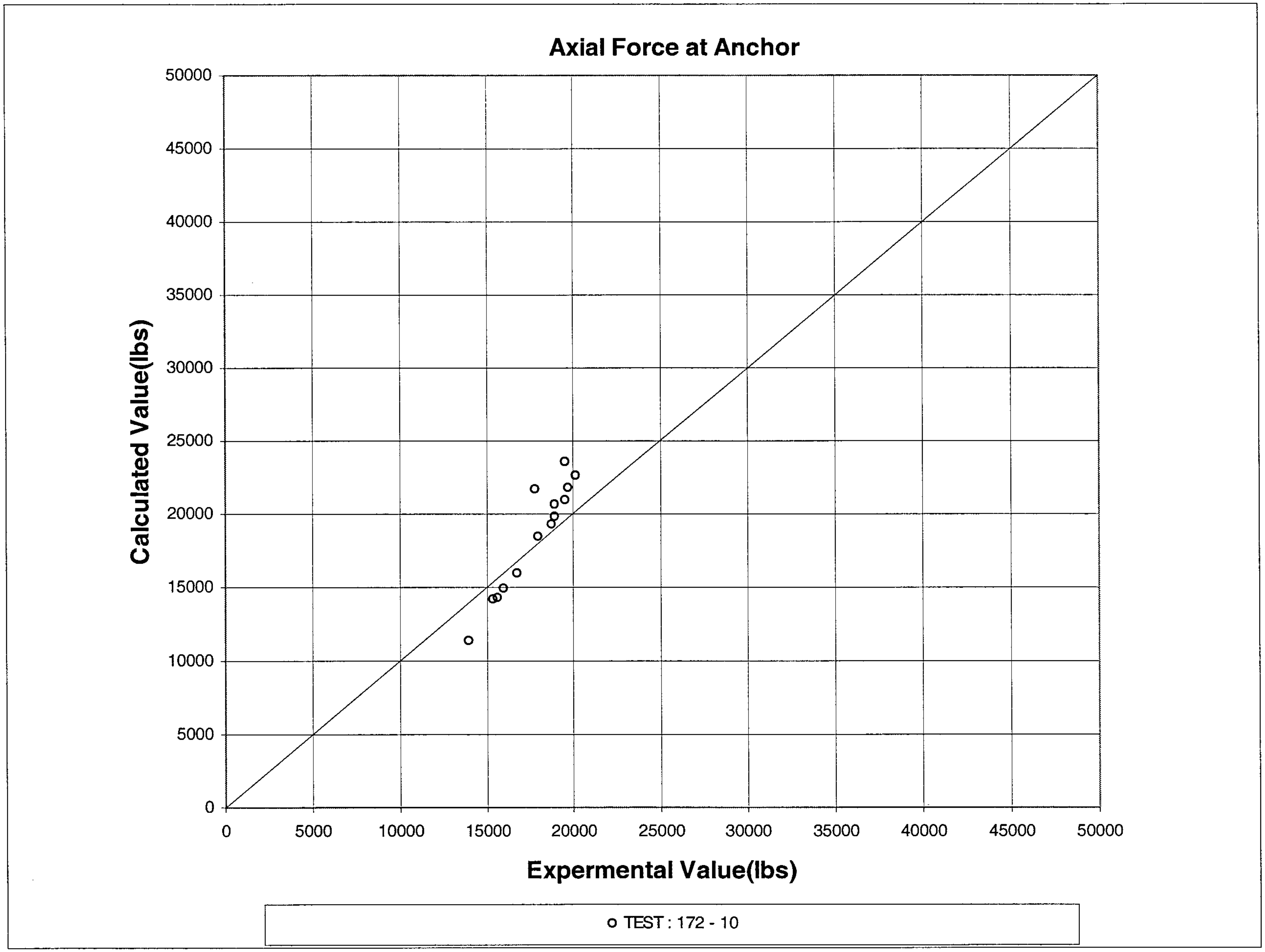
Axial Force at Anchor
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
Calculated Value(lbs)
Expermental Value(lbs)
TEST : 172 - 7



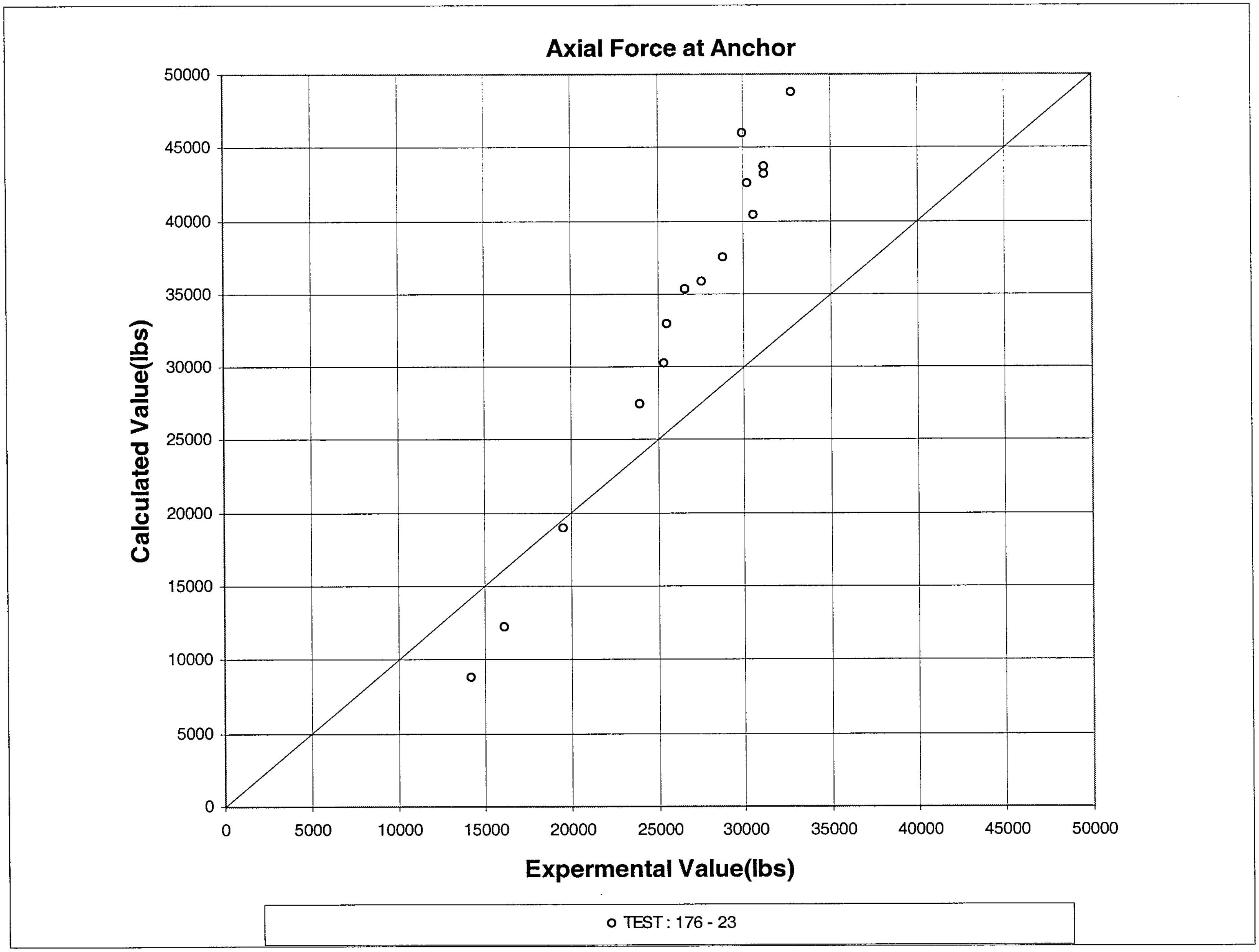
Axial Force at Anchor
Calculated Value(lbs)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0

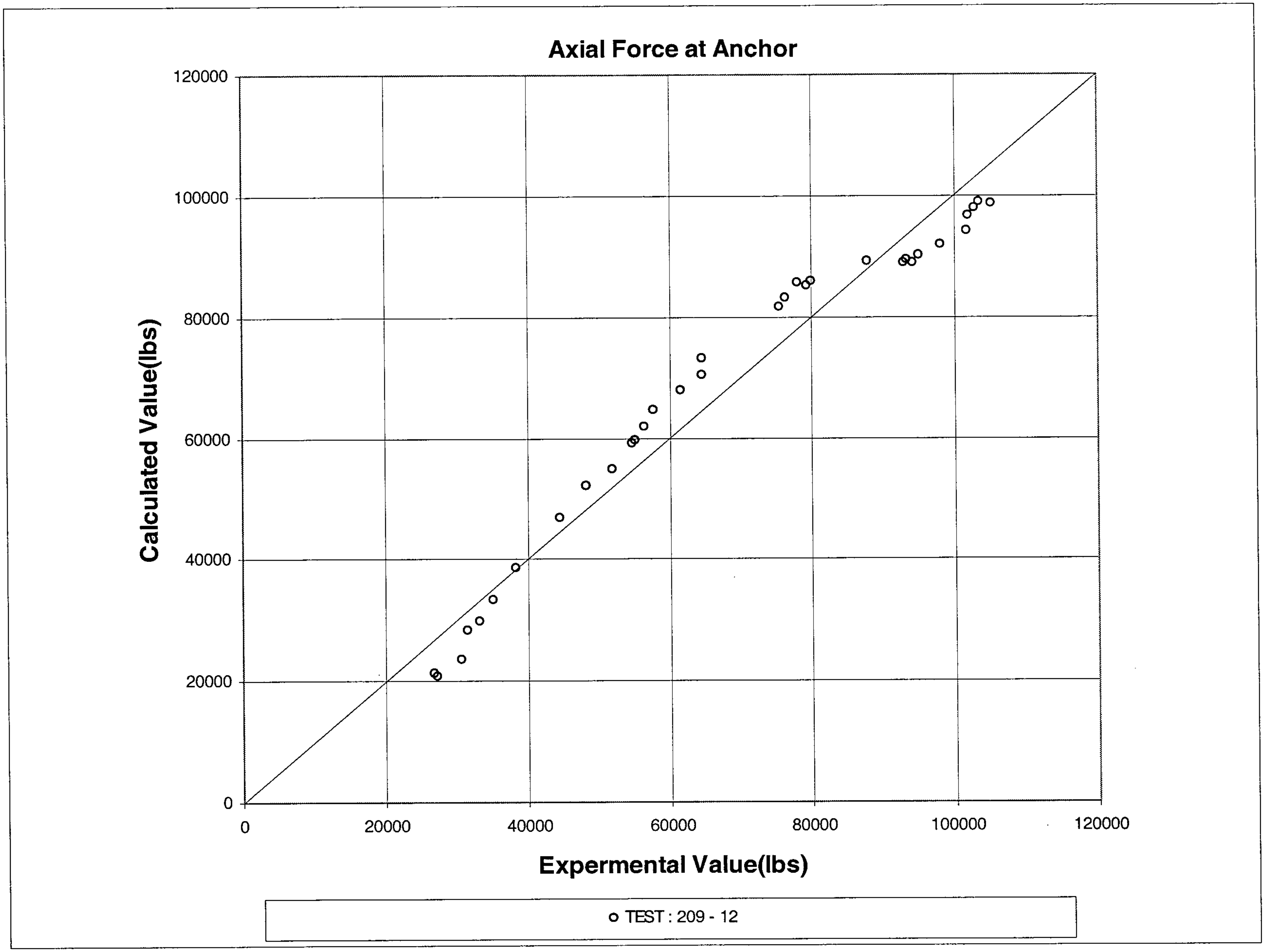


Axial Force at Anchor
50000
45000

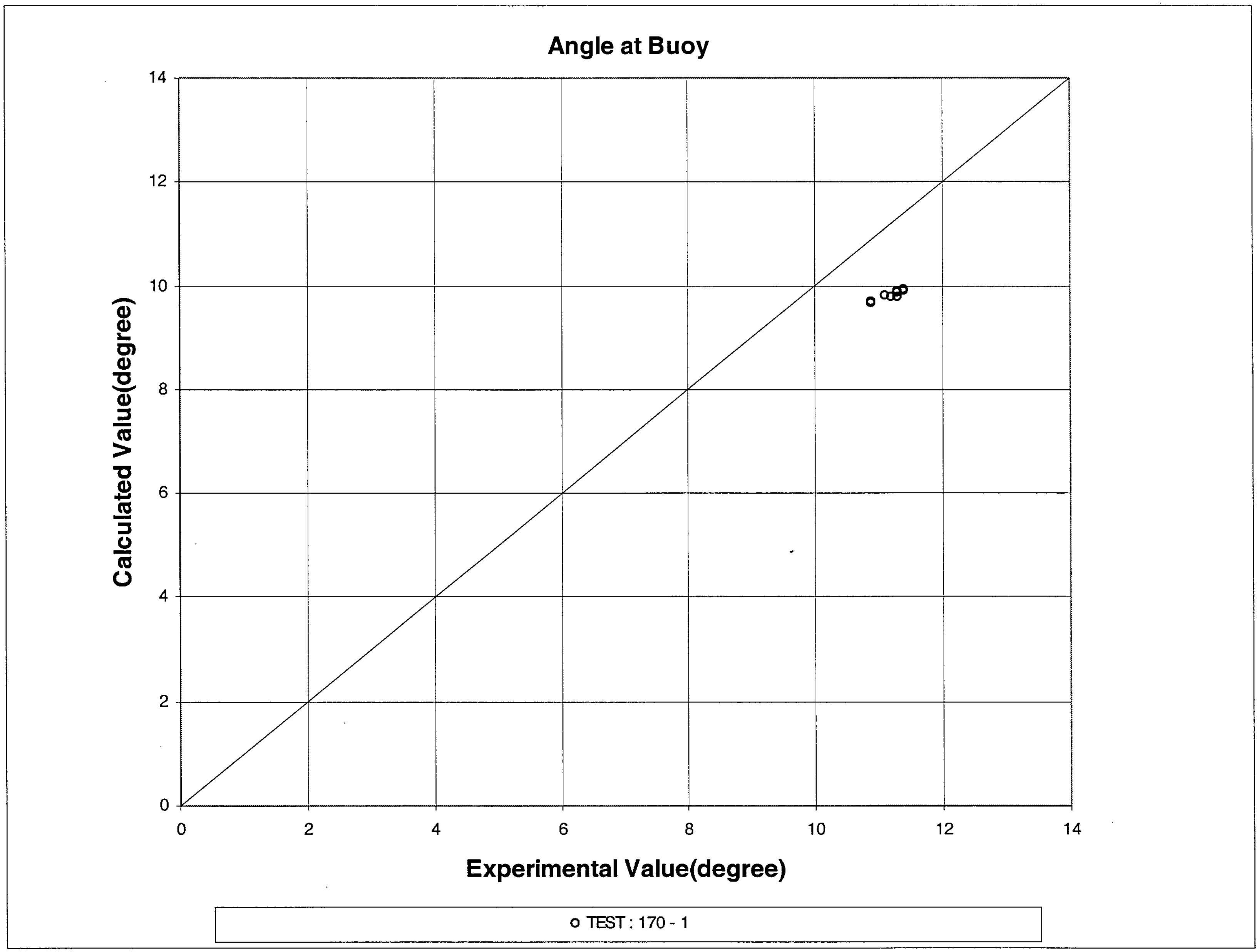


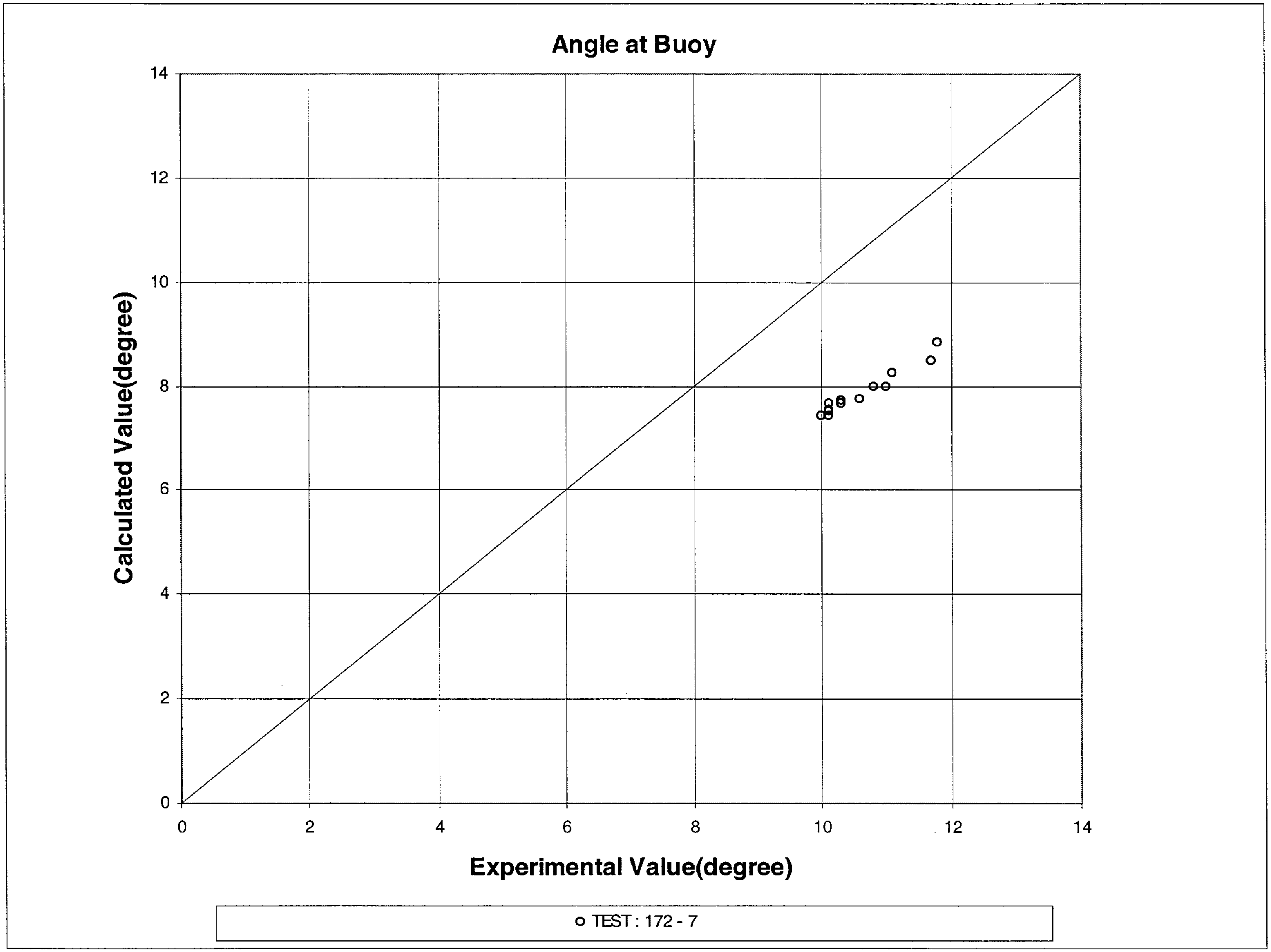
Axial Force at Anchor
Calculated Value(lbs)
Expermental Value(lbs)
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
o TEST : 172 - 10


Axial Force at Anchor
Calculated Value(lbs)
50000
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
0
5000
10000
15000
20000
25000
30000
35000
40000
45000
50000
Expermental Value(lbs)
TEST : 176 - 23

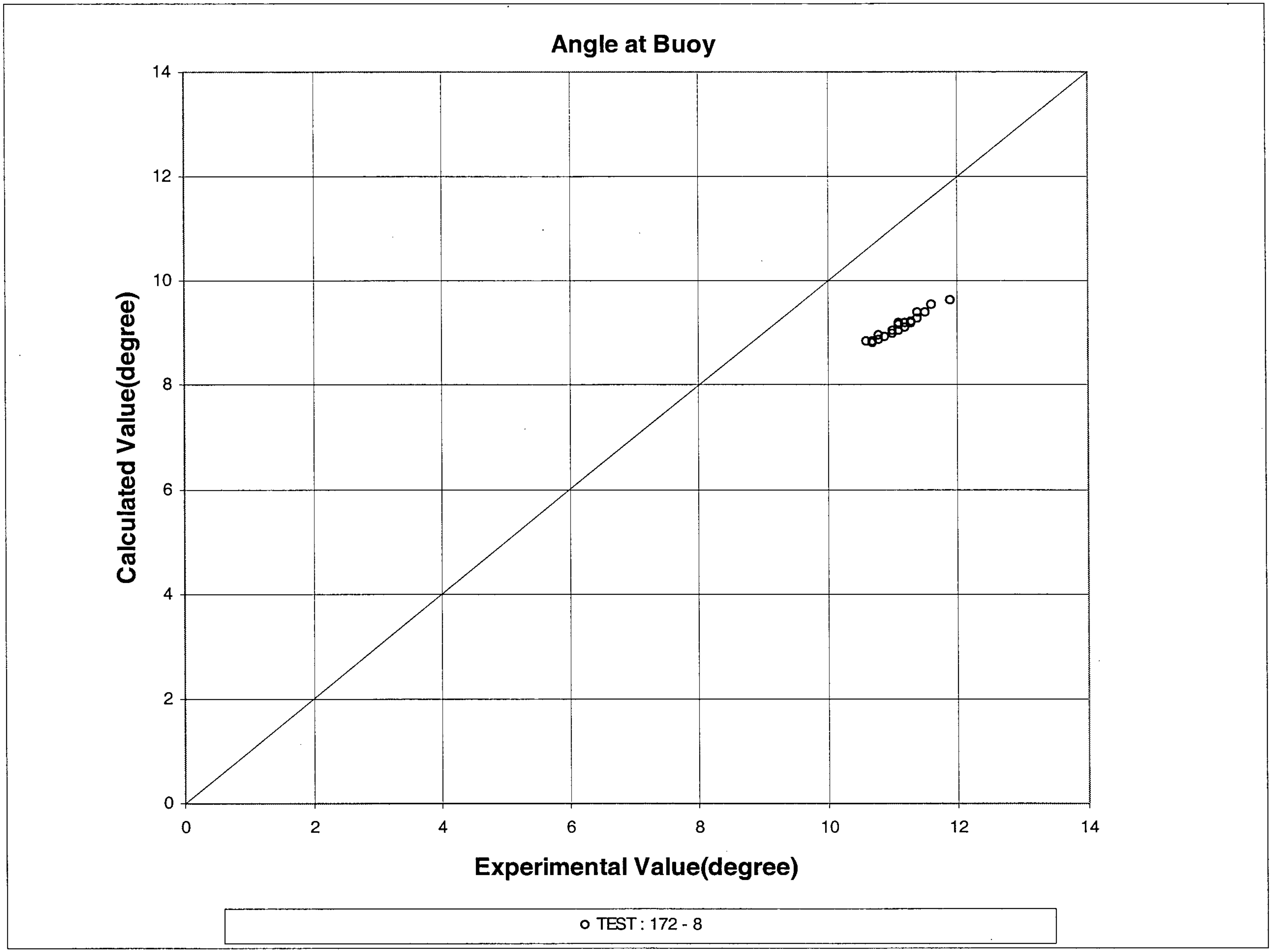


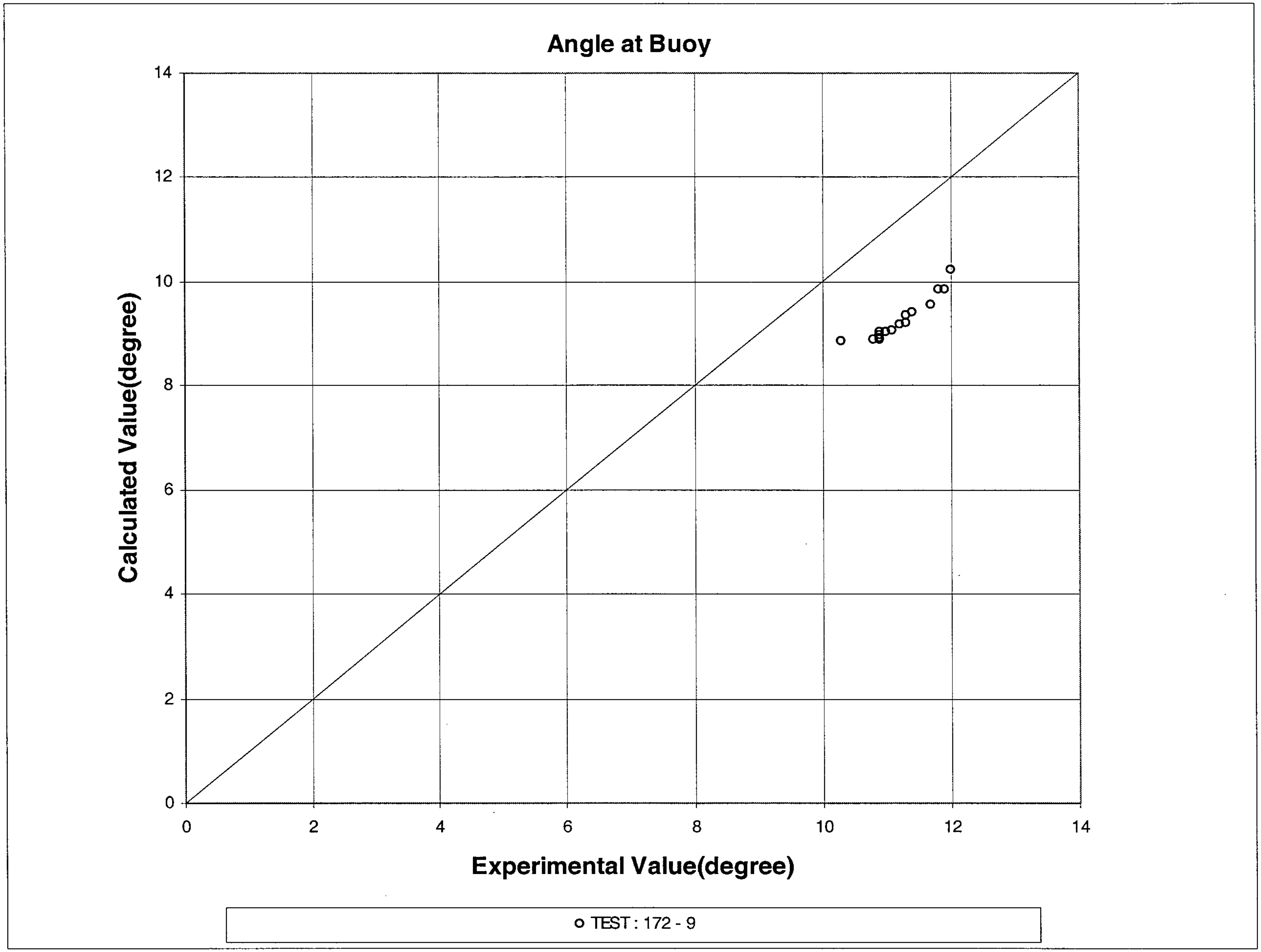
Axial Force at Anchor
Calculated Value(lbs)
Expermental Value(lbs)
0
20000
40000
60000
80000
100000
120000
TEST : 209 - 12

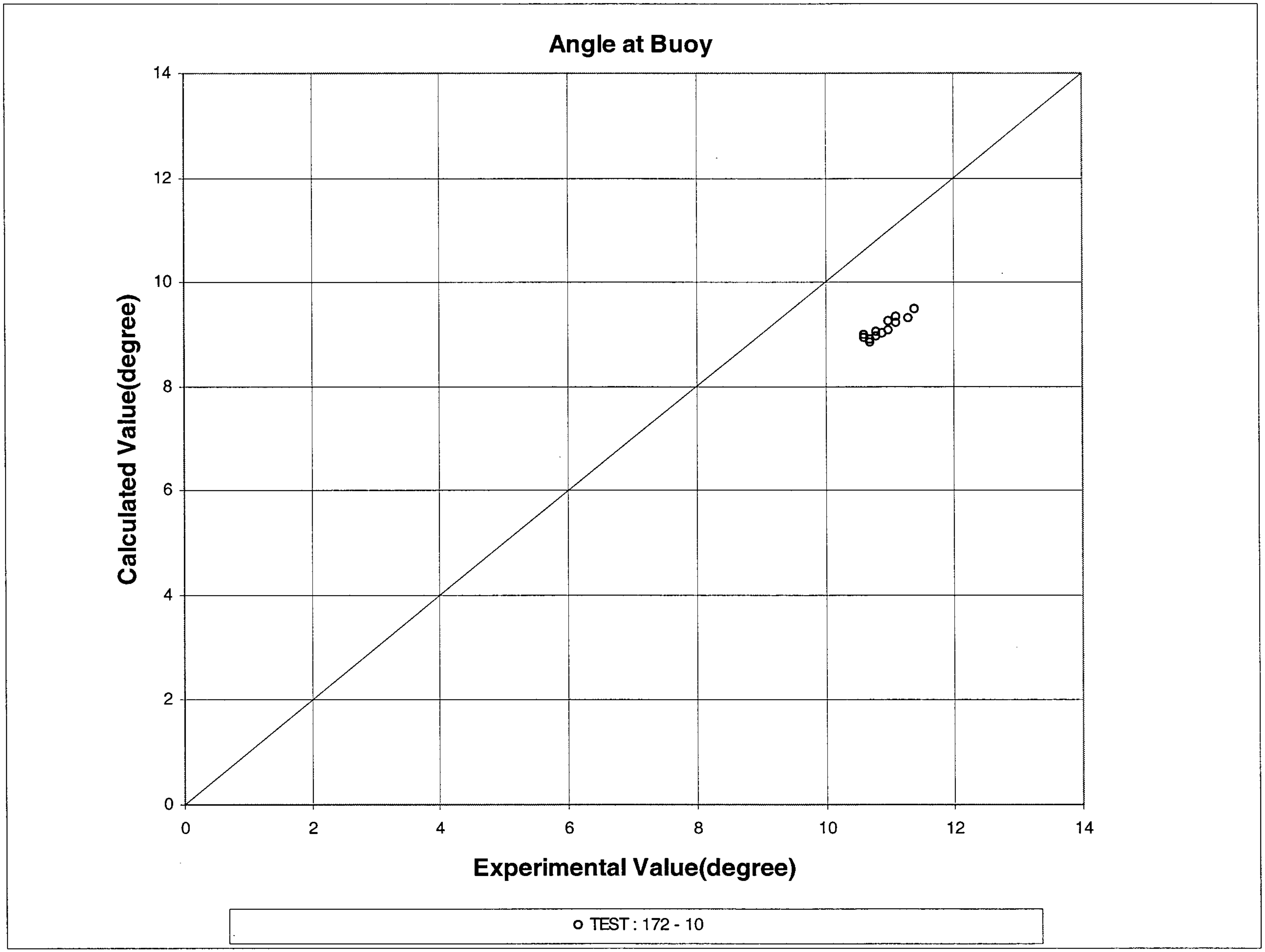

Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
2
4
6
8
10
12
14
o TEST : 170 - 1



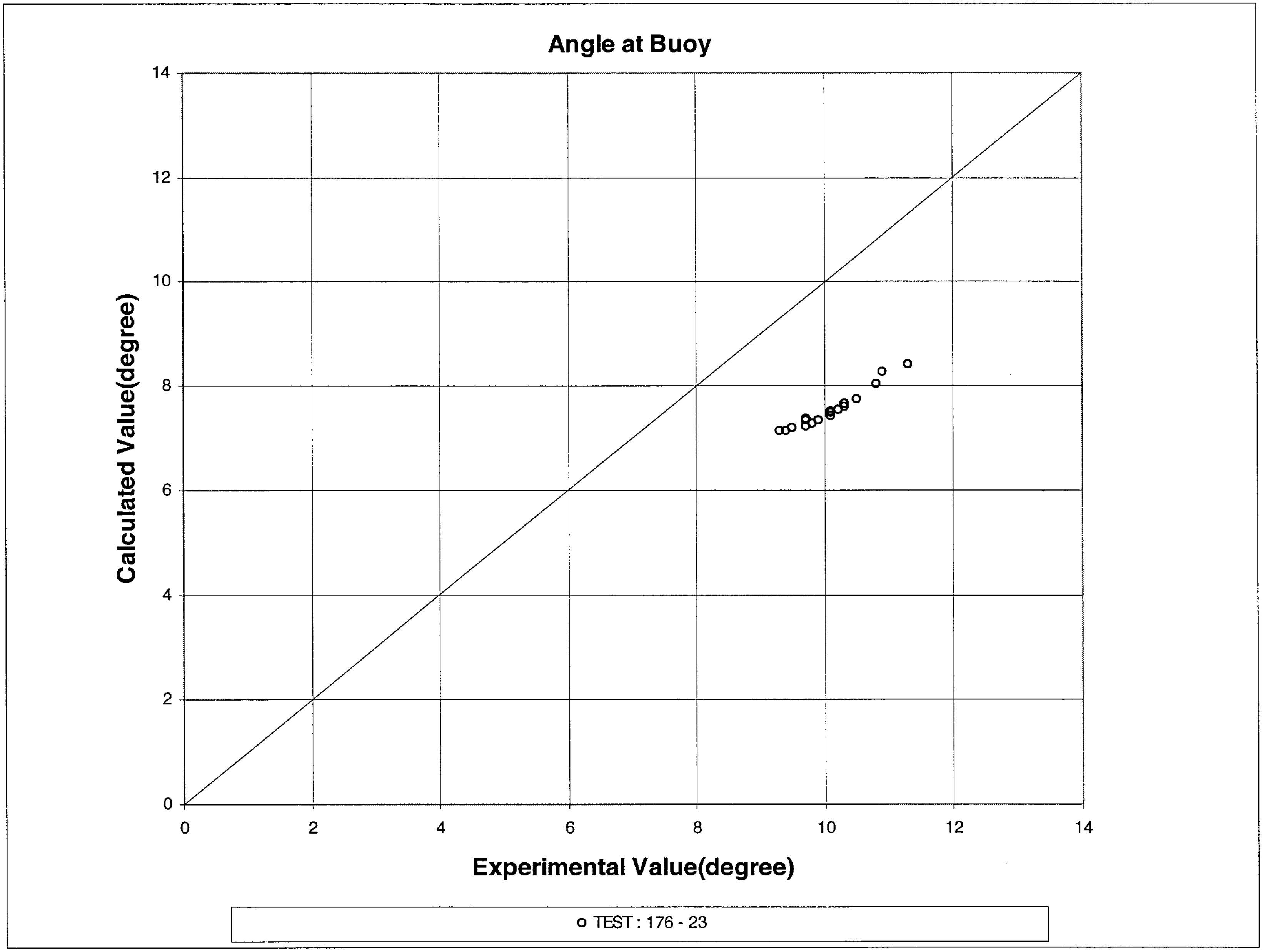
Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
2
4
6
8
10
12
14
TEST : 172 - 7


Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
2
4
6
8
10
12
14
TEST : 172 - 8

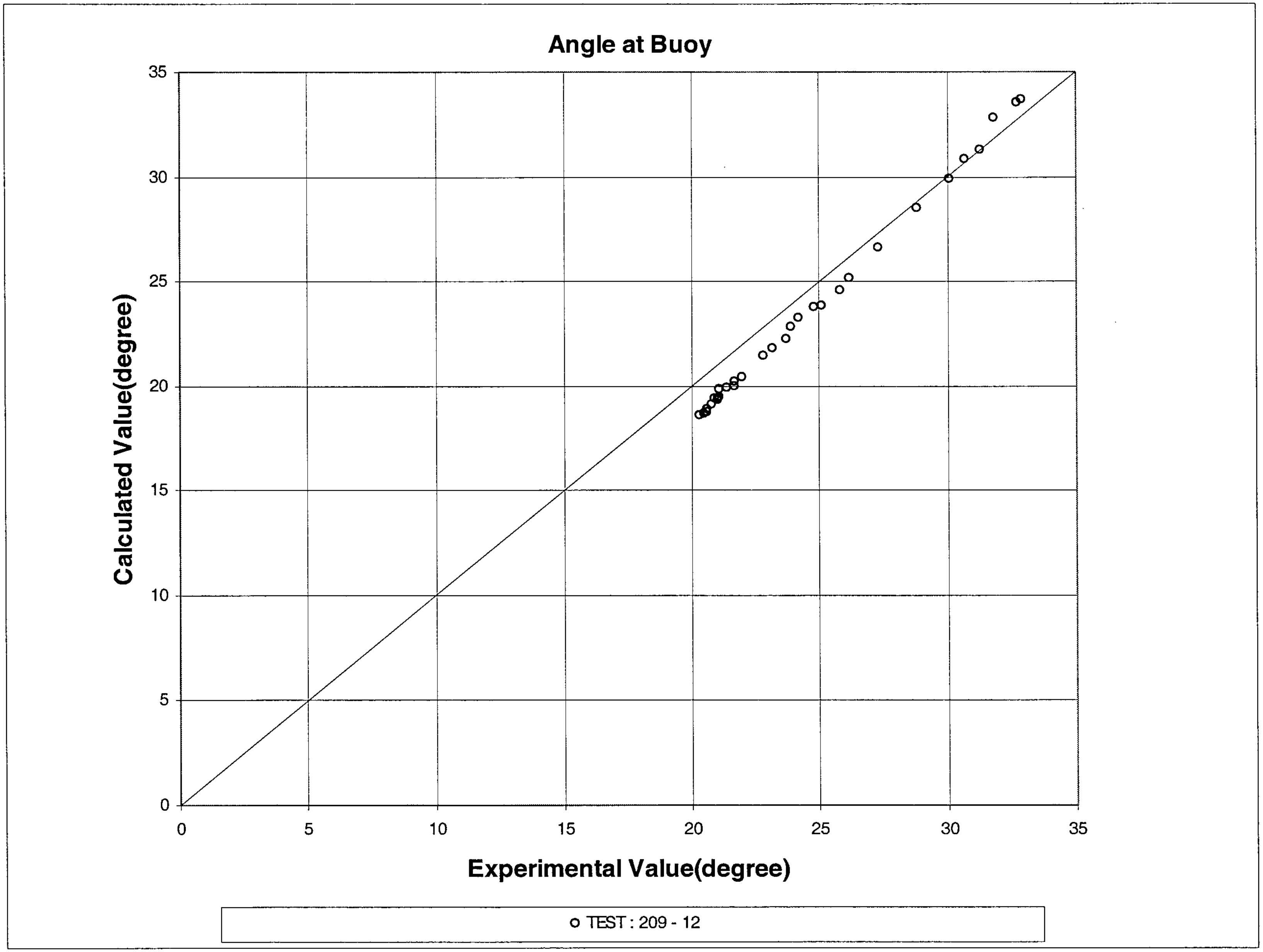

Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
2
4
6
8
10
12
14
TEST : 172 - 9



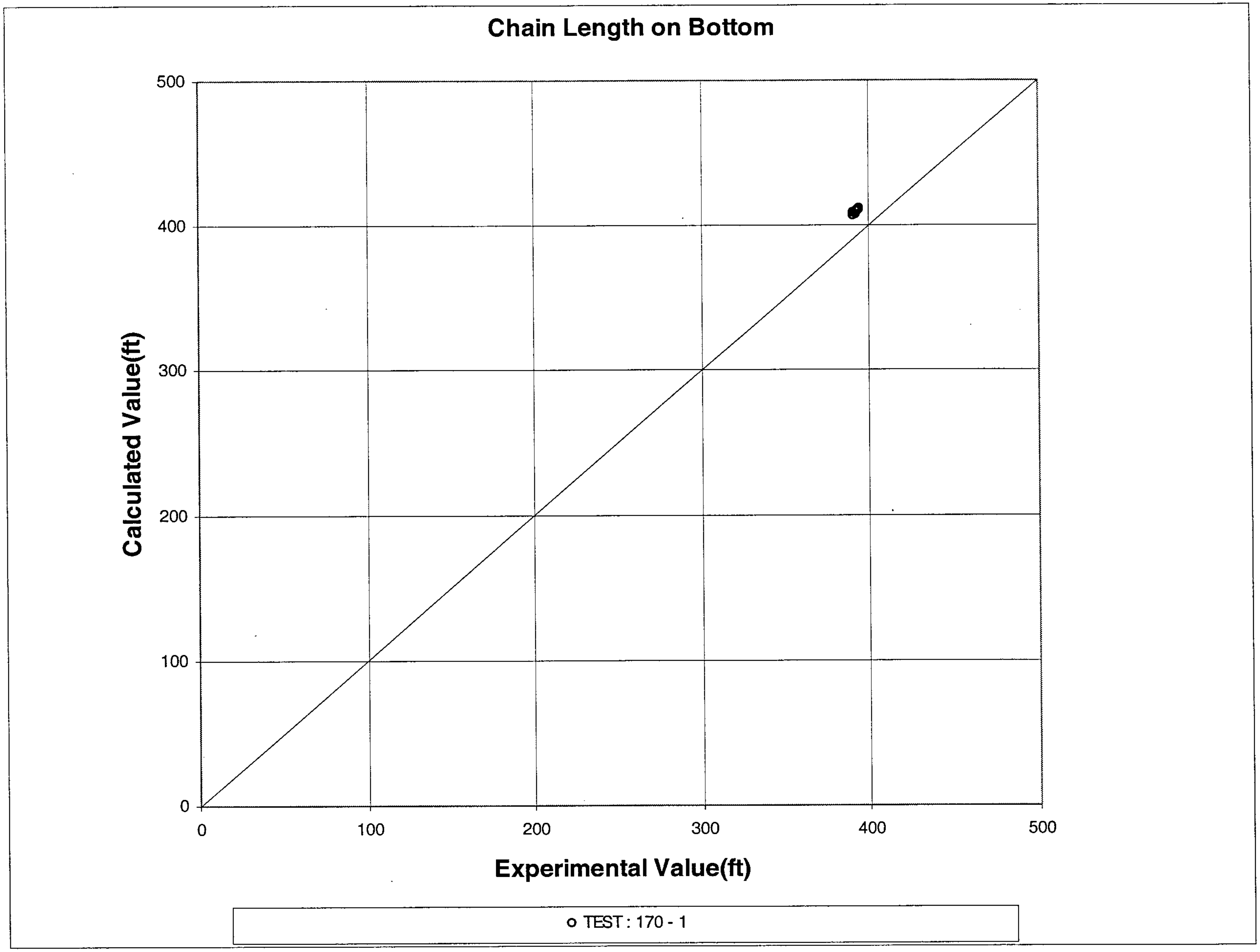
Angle at Buoy
14
12
10
8
6
4
2
0
Calculated Value(degree)
0
2
4
6
8
10
12
14
Experimental Value(degree)
TEST : 172 - 10

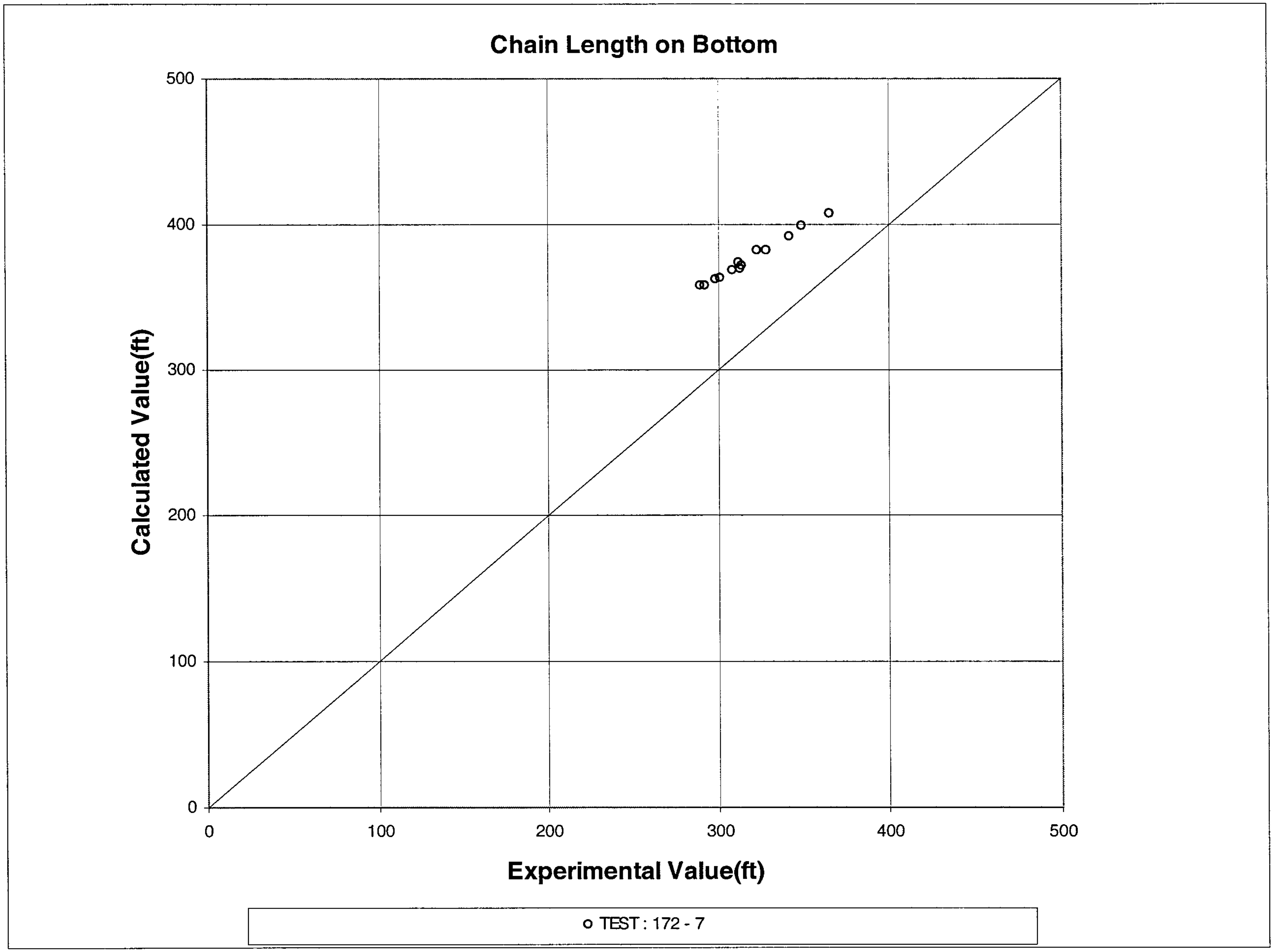


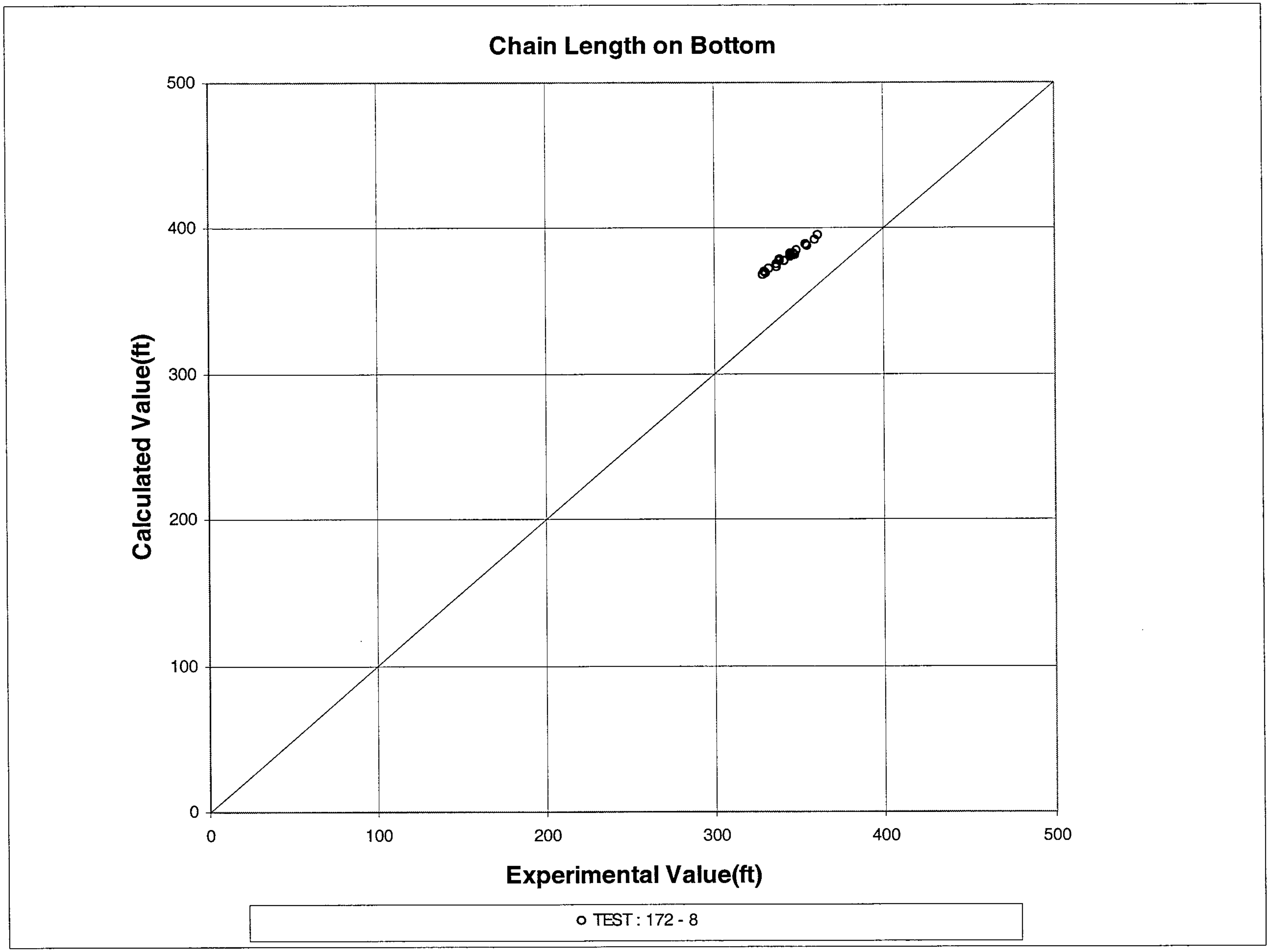
Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
2
4
6
8
10
12
14
o TEST : 176 - 23

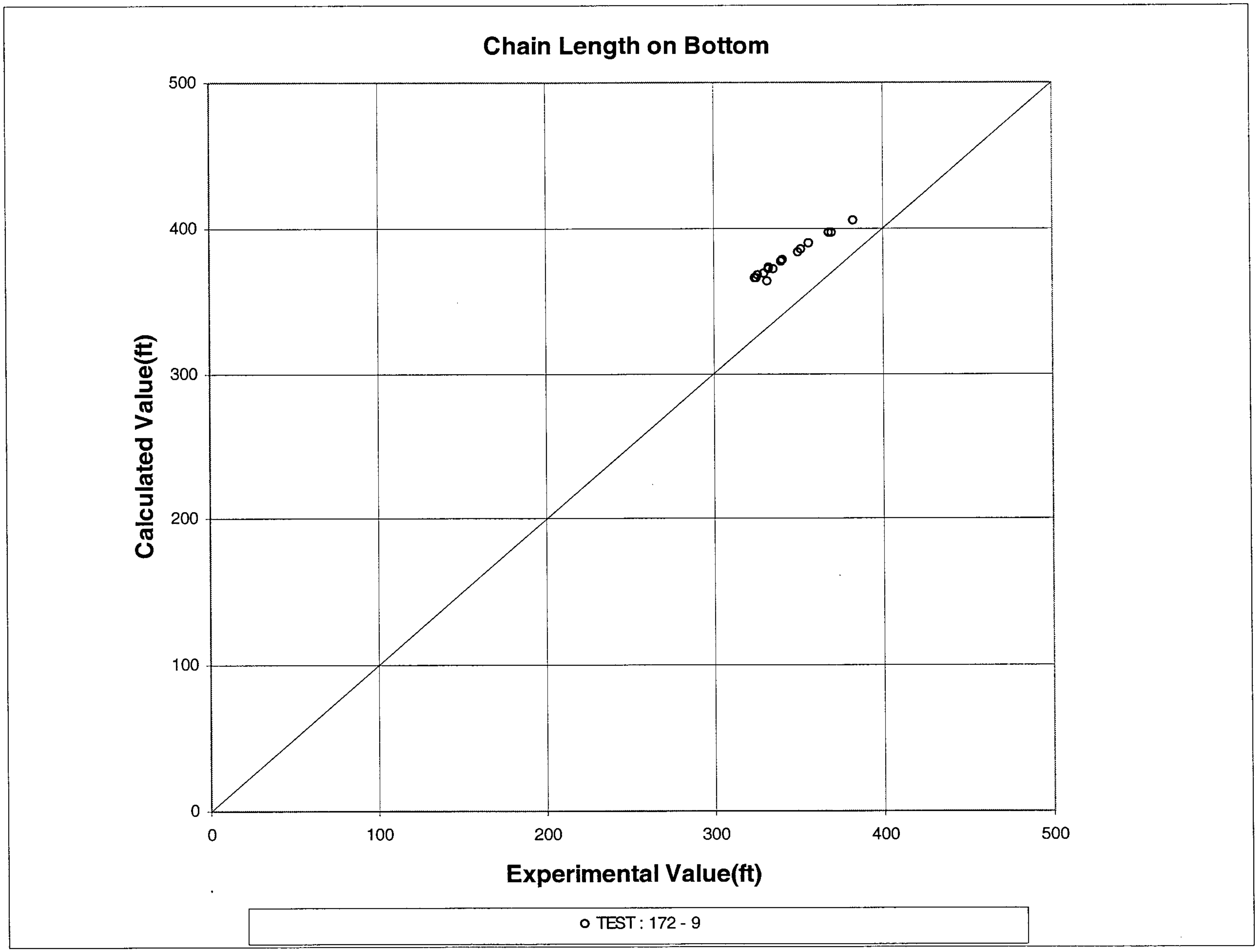


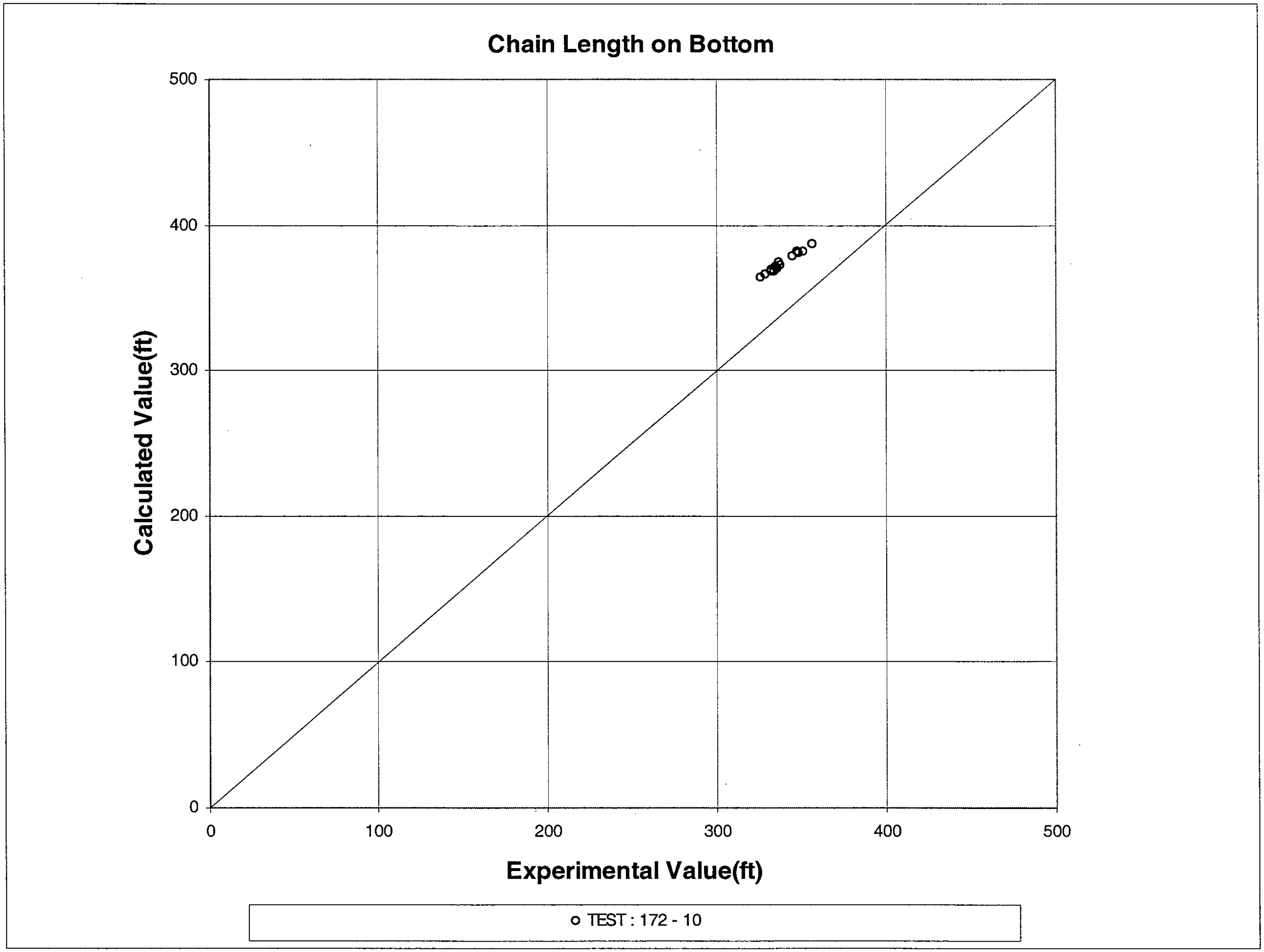
Angle at Buoy
Calculated Value(degree)
Experimental Value(degree)
0
5
10
15
20
25
30
35
TEST : 209 - 12


Chain Length on Bottom
Calculated Value(ft)
0
100
200
300
400
500
Experimental Value(ft)
TEST : 170 - 1

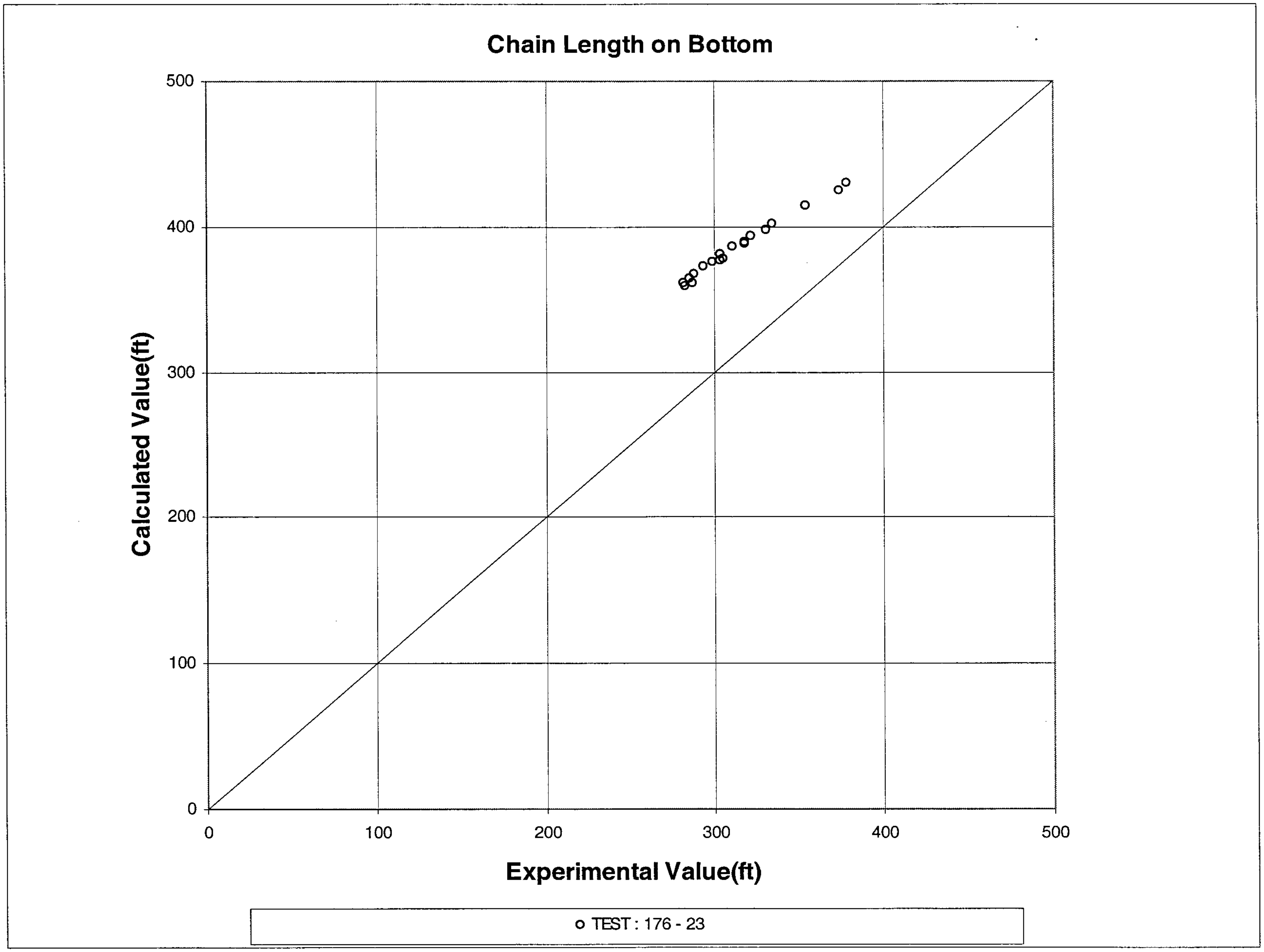

Chain Length on Bottom
Calculated Value(ft)
500
400
300
200
100
0
0
100
200
300
400
500
Experimental Value(ft)
TEST : 172 - 7

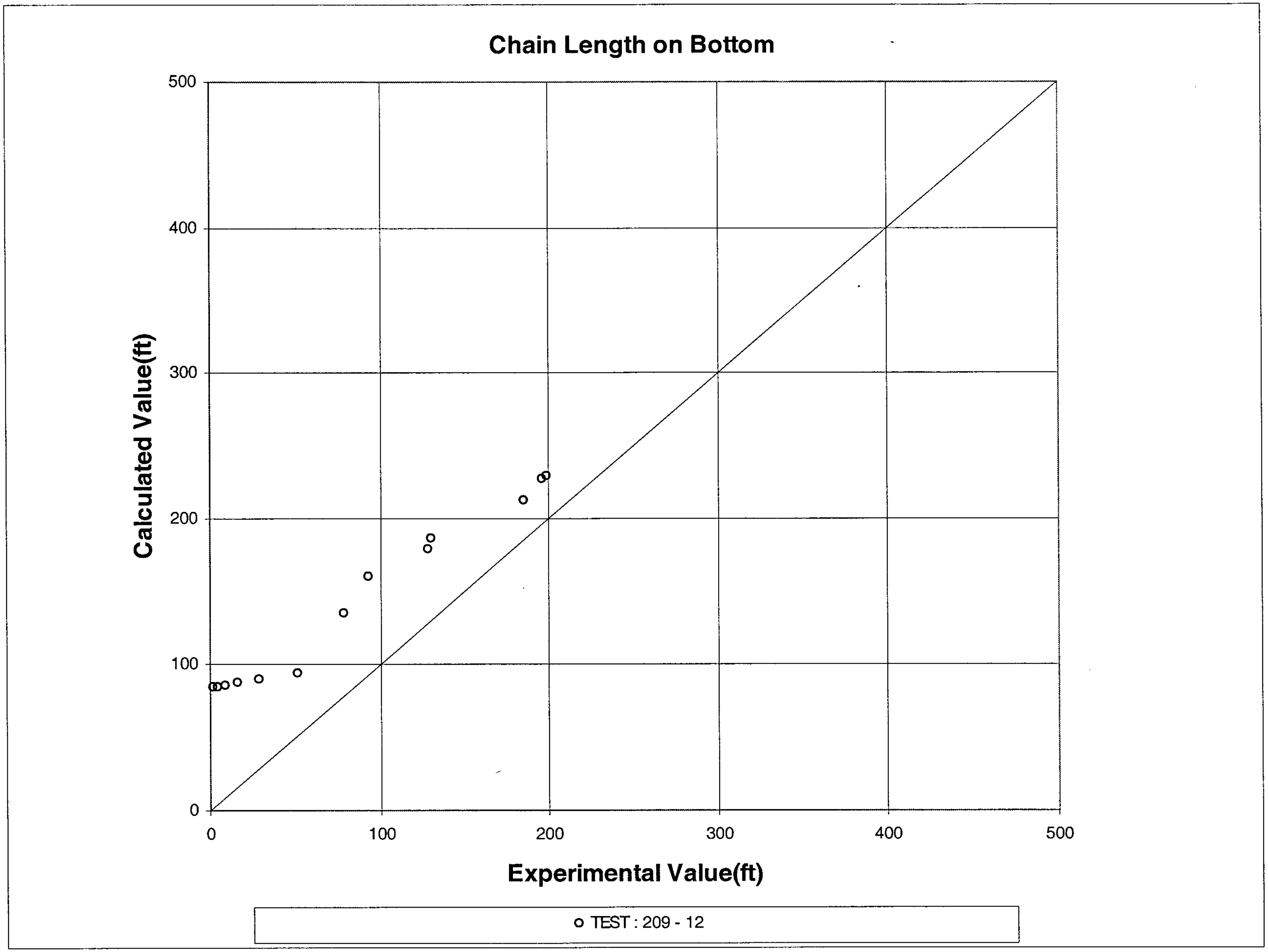

Chain Length on Bottom
Calculated Value(ft)
500
400
300
200
100
0
0
100
200
300
400
500
Experimental Value(ft)
TEST : 172 - 8


Chain Length on Bottom
Calculated Value(ft)
500
400
300
200
100
0
0
100
200
300
400
500
Experimental Value(ft)
TEST : 172 - 9



Chain Length on Bottom
Calculated Value(ft)
500
400
300
200
100
0
0
100
200
300
400
500
Experimental Value(ft)
TEST : 172 - 10


Chain Length on Bottom
Calculated Value(ft)
500
400
300
200
100
0
0
100
200
300
400
500
Experimental Value(ft)
TEST : 176 - 23


Chain Length on Bottom
Calculated Value(ft)
Experimental Value(ft)
0
100
200
300
400
500
0
100
200
300
400
500
o TEST : 209 - 12